REPORT TO THE LEGISLATURE PURSUANT TO ACT 41, SECTION 42 (2023)

Report on Excessive Motor Vehicle Noise

December 20, 2024

submitted to

The Vermont House and Senate Committees on Transportation
The Vermont House and Senate Committees on Judiciary

VERMONT
AGENCY OF TRANSPORTATION

Report Preparation

This report was prepared by SLR International Corporation (SLR) for the Vermont Agency of Transportation (VTrans).

The following organizations were consulted in the preparation of this report:

Vermont Agency of Transportation

Vermont Agency of Transportation, Department of Motor Vehicles

Vermont League of Cities and Towns

Vermont State Police

Vermont Sheriff's Association

Vermont Association of Chiefs of Police

Authorizing Legislation

Act 41, *An Act Relating to Miscellaneous Changes to Laws Related to Vehicles*, enacted June 1, 2023, contains the following provision in Section 42:

> EXCESSIVE MOTOR VEHICLE NOISE REPORT
>
> (a) The Commissioner of Motor Vehicles, in consultation with the Commissioner of Public Safety and the Vermont League of Cities and Towns, shall study and report on current and potential enforcement practices around excessive motor vehicle noise and make recommendations on ways to limit excessive motor vehicle noise in Vermont.
>
> (b) The study and report shall, at a minimum, address:
>
> (1) if there should be a noise standard in statute or the Periodic Inspection Manual, or both, and, if so, what that standard should be;
>
> (2) costs to incorporate noise testing into the State motor vehicle inspection required under 23 V.S.A. § 1222 and the State's Periodic Inspection Manual;
>
> (3) costs to train law enforcement officers on noise testing;
>
> (4) possible options to address excessive motor vehicle noise that do not involve noise testing such as visual inspections for modifications to a motor vehicle's exhaust system, whether as part of enforcement of the State motor vehicle inspection, and labeling on one or more components of a motor vehicle's exhaust system; and
>
> (5) approaches to minimize excessive motor vehicle noise that have been taken in other states, including increased enforcement by law enforcement coupled with an objective noise standard defense.

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Executive Summary

Purpose

Act 41, Section 42 enacted on June 1, 2023, directs the Vermont Agency of Transportation to submit a report to the Legislature on excessive motor vehicle noise. This report addresses the five topics specified in the legislation.

Issue and Context

Currently, the State of Vermont does not have a quantitative noise limit for vehicle noise. Essentially, the current Vermont motor vehicle laws that relate to noise are limited to ensuring that all vehicles are in good mechanical condition and properly equipped with a muffler. The inspection guidance limits the scope of the inspection to "parts or systems that are relevant to a vehicle's safe operation". There are no objective standards or quantitative methods in the law to define good mechanical condition, other than referring to "as installed by the manufacturer".

Methodology

Interviews were conducted with the Vermont Department of Public Safety, the Vermont League of Cities and Towns, the Vermont Sheriff's Association, the Vermont Association of Police Chiefs, the Vermont State Police, and VTrans. Interviews were focused on determining the scope of noise issues, the level of support for vehicle noise legislation and regulation, experience with vehicle noise testing and enforcement, including potential costs and implementation challenges, and experience with non-testing options for vehicle noise regulations. In addition to stakeholder interviews, noise regulations and legislation from nearby states, and for municipalities in Vermont that have vehicle noise regulations were reviewed. The Department of Motor Vehicles also commissioned a study from Parsons, the vendor for the Vermont Automated Vehicle Inspection Program (AVIP), that researched possible technologies which could be incorporated into the AVIP to measure vehicle noise. The Parsons report included cost estimates for software updates to the AVIP.

Potential Approaches

Table 1 provides a summary of some potential approaches for addressing vehicle noise, along with cost estimates. The approaches include:

1) Visual Inspection - change the Vermont Periodic Inspection Manual (VPIM) requiring inspection mechanics to reject modified or excessively noisy exhausts for passenger vehicles / light trucks (based on subjective observation),
2) Noise testing as part of the VPIM - integrate testing with the Automated Vehicle Inspection Program (AVIP) Tablet system,
3) Noise testing in statute with law enforcement – develop a framework and training to enable law enforcement to perform vehicle noise testing and enforce a noise statute,
4) Noise testing in statute – Inspection after citation – this is a hybrid approach that would give law enforcement the ability to issue citations for excessive vehicle noise based on a subjective assessment and would allow for the cited individual to take the vehicle in for testing at an inspection

station. If sound levels meet the ordinance limits during testing then the citation would be dismissed, and

5) Noise testing in statute - Drive-by-Monitoring by sound level meter (SLM) or acoustic camera – autonomous measurement of vehicle noise similar to a speed or red-light camera.

More detailed descriptions of the approaches and associated costs are provided in Sections 4.0 and 4.2 of this report. Other approaches are discussed at the end of the report, for which costs were not available. These include potential labeling of exhaust systems (mufflers) and public awareness campaigns.

Table 1: Summary of Options and Costs

Option	Description of Steps	Expected Efficacy	Cost Estimate, $	
			One Time	Annual Recurring
1) Visual Inspection - Change VPIM to require inspection mechanics to reject modified or excessively noisy exhausts for passenger vehicles / light trucks	1) Update rules through APA, 2) Update and reissue VPIM, 3) Update AVIP software to reflect changes, and 4) Marketing / education campaign to train inspection mechanics on changes	**Low**	**31,400**	**-**
2) Noise Testing - as part of the VPIM - Vehicle inspection mechanics as enforcement	1) Update rules through APA, 2) Update and reissue VPIM, 3) Update AVIP software to reflect changes, 4) Purchase sound level meters for inspection stations, 5) Develop marketing / education campaign to train inspection mechanics on changes, and 6) Annual calibration and maintenance for equipment.	**Low to Moderate**	**644,200**	**110,000**
3) Noise Testing - in Statute - Law enforcement as enforcement	1) Update Legislation, 2) Develop one-hour training course for officers, 3) Purchase sound level meters for law enforcement, 4) Train officers on sound level meter use, 5) Annual calibration and maintenance plan for equipment, 6) Implement annual training program	**Moderate**	**267,200**	**75,000**
4) Noise Testing - in Statute - Inspection After Citation (**30 testing stations** are included in the cost estimate)	1) Update Legislation, 2) Develop one-hour training course for officers, 3) Update AVIP software to reflect changes, 4) Purchase sound level meters for inspection stations, 5) Develop marketing / education campaign to train inspection mechanics on changes, and 6) Annual calibration and maintenance for equipment.	**Moderate**	**174,400**	**2,750**
5) Noise Testing - in Statute – Automated Drive-by-Monitoring by sound level meter or acoustic camera (**10 monitoring locations** are included in the cost estimate)	1) Update Vermont statutes to allow remote enforcement via civil action, 2) Purchase and install fixed-position or mobile drive-by noise monitoring stations, 3) Develop software for automated civil action generation, and 4) Develop calibration and maintenance plan for equipment	**High -** for acoustic cameras, **Moderate-** for sound level meters	**450,000**	**36,000**

Table 2: Summary of Challenges and Benefits

Option	Challenges	Benefits
1) Visual Inspection - Change VPIM to require inspection mechanics to reject modified or excessively noisy exhausts for passenger vehicles / light trucks	Affects all vehicles - not just noisy ones, Adds a step to the inspection process, May lead to failure for aftermarket exhausts which do not increase noise levels, May limit Vermont consumer's ability to use aftermarket or non-OEM parts, Requires inspection mechanics to make a judgement call on excessive noise and/or aftermarket status of equipment, Low efficacy - vehicle owners can remove aftermarket mufflers before inspections and then reinstall them after passing inspection, Subjective - does not have an objective / quantitative limit, Will not detect vehicle noise due to motion such as engine braking noise, loud stereos, etc.	Ease of implementation, Low cost and no recurring cost, Uses existing inspection system.
2) Noise Testing - as part of the VPIM - Vehicle inspection mechanics as enforcement	Affects all vehicles - not just noisy ones, Difficult to determine the appropriate sound level limit, Difficult to test noise in a shop environment, Inspection stations may need to find alternative test locations, Inspection stations may not be willing to incur additional equipment costs, Additional equipment required, Additional time and cost for Vermont residents during inspections, Low efficacy - vehicle owners can remove aftermarket mufflers before inspections and then reinstall them after passing inspection, Recurring annual costs due to meter maintenance and calibration, Will not detect vehicle noise due to motion such as engine braking noise, loud stereos, etc.	Implements an objective standard, All vehicles tested, No additional burden on law enforcement.
3) Noise Testing - in Statute - Law enforcement as enforcement	Difficult to test noise on the side of road, Difficult to determine the appropriate sound level limit, Law enforcement must make a subjective determination of which cars to test, Only subjectively noisy vehicles tested so some noisy vehicles may be missed, Additional demand on limited law enforcement resources - diverts traffic stop attention away from speed / DUI / other safety enforcement, Law enforcement may not use or implement noise testing equipment due to other obligations, Standard must be defensible in court	Implements an objective standard, Testing occurs on vehicles as they are driven, not during a scheduled test - this eliminates owners removing aftermarket mufflers before inspections, Testing can be performed while vehicle is in motion to detect vehicle noise such as engine braking noise, loud stereos, etc.
4) Noise Testing - in Statute - Inspection after citation	Requires a subjective judgement by law enforcement to issue citation Only subjectively noisy vehicles tested so some noisy vehicles may be missed, Additional demand on limited law enforcement resources - diverts traffic stop attention away from speed / DUI / other safety enforcement, Difficult to determine the appropriate sound level limit, Difficult to test noise in a shop environment,	Implements an objective standard after a subjective citation, Only effects vehicles which are subjectively noisy, Gives law enforcement a method to control excessive vehicle noise that doesn't require additional equipment

Option	Challenges	Benefits
	Inspection stations may need to find alternative test locations, Inspection stations may not be willing to incur additional equipment costs, Additional equipment required, Additional time and cost for cited individuals, based on a subjective judgement by law enforcement, Low efficacy - vehicle owners can remove aftermarket mufflers before the defense inspection and then reinstall them after passing inspection, Smaller number of testing stations so may be inconvenient for cite individuals to find a testing station, Recurring annual costs due to meter maintenance and calibration, Will not detect vehicle noise due to motion such as engine braking noise, loud stereos, etc.	Gives cited individuals an objective defense Significantly lower startup and recurring costs than other noise testing options With limited testing stations, fewer sound level meters need to be purchased, less training, and lower annual recurring costs
5) Noise Testing - in Statute – Automated Drive-by-Monitoring by sound level meter or acoustic camera	Will require changes to Vermont statutes to allow unattended / remote enforcement, High cost per location, Requires software development and system integration, Potential legal challenges to accuracy and repeatability - similar to speed cameras, SLMs will not isolate individual vehicles except in specially configured locations, Standard must be defensible in court.	Implements an objective standard, No additional burden on law enforcement, Measures vehicles in motion as they are driven so will enforce consistent limits for all vehicle noises - exhausts, engine braking, stereos, and tire squeal, Acoustic cameras can isolate sound from specific vehicles

Summary of Findings

Challenges and Benefits

The question of whether there should be a noise standard in statute or as part of the VPIM is very complex. Noise standards can either be objective / quantitative and limit the sound level produced by a vehicle, or standards can be subjective / qualitative and require the presence of certain equipment or require a subjective assessment of whether the noise from a vehicle is typical or excessive. The challenges and benefits associated with each of the options explored in this report are summarized in Table 2.

Stakeholder Interviews

Stakeholders had mixed opinions about the need for a noise standard in Vermont statute or in the VPIM. Generally, feedback was against the need for a noise standard in statute or in the VPIM, due to the difficulty of implementing a noise standard and concerns about allocation of limited resources for enforcement.

Stakeholders had a range of concerns about expanding visual inspections in the VPIM, which primarily centered on the subjective nature of visual inspections, the additional demands subjective decisions would place on inspection mechanics, and the additional costs and time required for the inspection changes.

Some stakeholders expressed support for a noise standard in statute or in the VPIM. These stakeholders often referenced personal experiences with loud vehicles close to their residences or in their neighborhoods.

They also referenced anecdotes about noise as a negative environmental impact and referenced the presence of a few loud vehicles or a small number of significant offenders.

Findings

A change to the VPIM that would require inspection mechanics to reject modified or excessively noisy exhausts for passenger vehicles / light trucks would be the simplest and least costly to implement vehicle noise control measure. This option would likely also be the least effective, as it is subjective and vehicle owners can remove aftermarket mufflers before inspections and then reinstall them after passing inspection.

Noise testing as part of the VPIM would provide an objective standard for vehicle noise levels and could be incorporated into the existing Automated Vehicle Inspection Program (AVIP) software. This is the most expensive option evaluated, due to the number of sound level meters that would have to be purchased, calibrated, and maintained.

Noise testing could also be instituted in statute with enforcement performed by law enforcement personnel. This would require less equipment than implementing testing in the VPIM, but it would add additional training and enforcement responsibilities to law enforcement, potentially to the detriment of other safety enforcement activities that stakeholders considered to be higher priority.

Acoustic cameras are an emerging technology that use a large array of microphones to determine not just the sound level but also the source of the sound. Using an acoustic camera-based automated testing systems could provide a scalable, objective vehicle noise testing solution that would not add any additional burden to law enforcement or inspection stations. This option would require modifications to existing Vermont Statutes to allow unattended / remote enforcement. These changes are being investigated by other parties as part of research into the practicality of speed cameras. Costs in this report for this option are based on ten stations, but a pilot program could be implemented to investigate the feasibility of the system by using fewer stations. This would likely be the most effective option, as the acoustic cameras measure sound levels from vehicles in motion and are capable of isolating sound from the vehicle under investigation.

1.0 Purpose

1.1 Authorizing Legislation

Act 41, *An Act Relating to Miscellaneous Changes to Laws Related to Vehicles*, Section 42, *Report on Excessive Vehicle Noise*, enacted on June 1, 2023, directs the Vermont Agency of Transportation (VTrans) to submit a report to the Legislature on current and potential enforcement practices around excessive motor vehicle noise, and to make recommendations on ways to limit excessive motor vehicle noise in Vermont. The legislation requires that the study address five specific topics and called for participation by specific Vermont state agencies and external parties.

The five topics included in the legislative language in Section 42 are as follows:

1. If there should be a noise standard in statute or the Periodic Inspection Manual (PIM), or both, and, if so, what that standard should be;

2. Costs to incorporate noise testing into the Periodic Inspection Manual;

3. Costs to train law enforcement officers on noise testing;

4. Possible options to address excessive motor vehicle noise not involving noise testing (visual inspections, enforcement of the State motor vehicle inspection, and labeling of components of exhaust system components);

5. Approaches to minimize excessive motor vehicle noise from other states (increased enforcement by law enforcement coupled with an objective noise standard)

The five topics are discussed in more detail in Section 4.0 of this report.

1.2 Overview

Interviews were conducted with the Vermont Department of Public Safety, the Vermont League of Cities and Towns, the Vermont Sheriff's Association, the Vermont Association of Police Chiefs, the Vermont State Police, and VTrans. Interviews were focused on determining the scope of noise issues, the level of support for vehicle noise legislation and regulation, experience with vehicle noise testing and enforcement, including potential costs and implementation challenges, and experience with non-testing options for vehicle noise regulations.

In addition to stakeholder interviews, vehicle noise regulations and legislation from nearby states and for municipalities in Vermont that have vehicle noise regulations were documented. VTrans also commissioned a study from Parsons, the vendor for the Vermont Automated Vehicle Inspection Program (AVIP), which researched possible technologies that could be incorporated into the AVIP to measure vehicle noise. The Parsons report included cost estimates for software updates to the AVIP.

1.3 Background Information on Vehicle Noise

1.3.1 Types

There are several different vehicle components that generate noise. At low speeds, vehicle sounds are controlled by engine exhaust and radiator-fan noise. At higher speeds, in most vehicles, noise from the interaction between the tire and road controls vehicle sound levels. Other noise sources are related to the operation of the vehicle, such as squealing tires, stereo noise, and engine braking. Of these, based on stakeholder interview responses, the components that seem to be responsible for the most noise complaints are engine exhaust noise and engine braking.

Engine exhaust noise is typically effectively reduced by the vehicle manufacturer's exhaust system design, including some combination of catalysts, mufflers, and exhaust piping. However, some owners replace or modify exhaust systems with the intent of improving the engine performance by reducing exhaust system pressure drop or changing the sound of the exhaust to a louder, more-aggressive, sound. The sound of the modified, often louder, exhaust can be an annoyance for residents and neighbors. Additionally, exhaust system components degrade over time and their performance can be significantly reduced by rust perforation or loss of internal structure due to rust.

Engine braking, more properly known as compression release engine braking, and also known under its Jacobs Vehicle Systems brand name of "Jake Braking", is a system used in diesel engines that opens the engine exhaust valves during vehicle deceleration, so that the engine acts as an additional braking system. The braking effect can be significant and can be an important auxiliary braking system for large trucks. However, when the exhaust valves open, the compressed air in the cylinders is released and can generate loud jackhammer-like popping sounds. The compressed air from the engine is routed through the exhaust system, and the engine braking sound can be effectively attenuated by the exhaust system. Modified, aftermarket, or mufflers in poor condition can cause sound levels of 96 to 101 dBA at 50 feet compared to a muffled engine sound level of 80 to 83 dBA[1]. These engine braking sounds can be very annoying due to their impulsive high-amplitude qualities, and they are a common cause of complaints.

1.3.2 A-weighting and Sound Level Metrics

A-weighting is a standardized method in which sound pressure levels in individual frequency bands are adjusted to match the frequency response sensitivity of human hearing. The human ear is much less responsive at low frequencies than at mid and high frequencies. An A-weighted sound level is the total contribution from all sound frequencies, with the appropriate weighting factors applied. When discussing sound levels and descriptors/metrics, this report will refer to the A-weighted level (dBA), which is the most common weighting system used in the field of environmental acoustics.

Figure 1-1 presents a graph of common outdoor and indoor sound levels.

[1] "Muffling and Engine Brakes" Jacobs Vehicle Systems, 2022, https://www.cummins.com/sites/default/files/2024-01/Jacobs%20Vehicle%20Systems%20Engine%20Brake%20Noise%20Brochure.pdf, Accessed December 2024

Figure 1-1: Outdoor and Indoor Sound Levels Compared

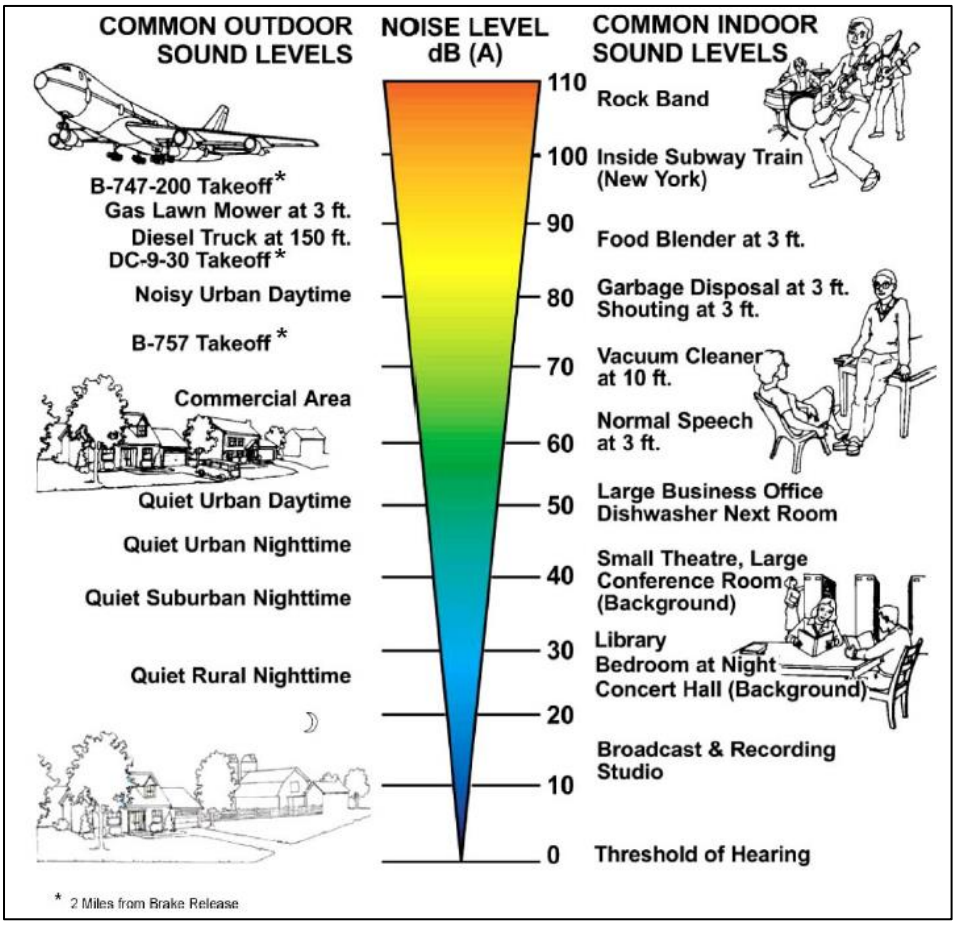
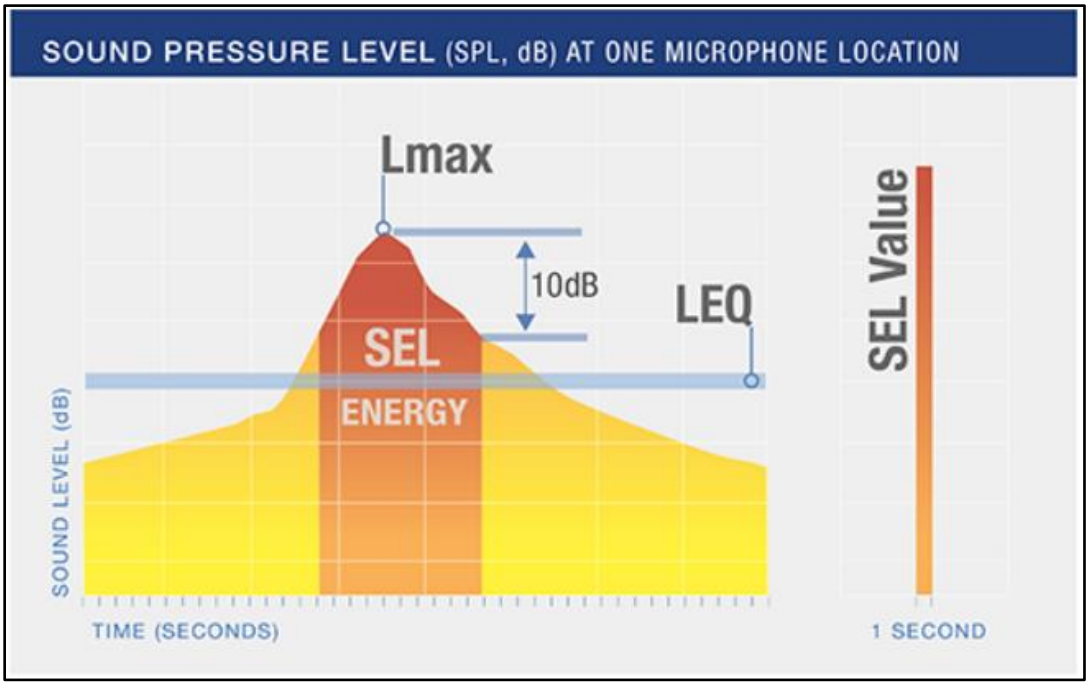


Figure 1-1 identifies a level of 80 dBA as “Noisy Urban Daytime” or “Shouting at 3 feet”. A level of 90 dBA would be expected from a “Gas Lawnmower at 3 feet”. Any sound level above 70-80 dBA could be considered “Loud” relative to a conversational level of 60 dBA. Experiencing a sound level of 90-100 dBA for a few seconds will not cause hearing damage, but it would be very noticeable to most listeners.

Discrete, brief-duration noises (sometimes called “transient” events) such as a loud vehicle passing by, are often described by their maximum A-weighted sound level (L_{max}) or by their Sound Exposure Level (SEL). The SEL metric represents all of the acoustic energy attributable to an individual noise event. The SEL is a “Single Event” metric and captures both the level and the duration of a sound event in a single numerical quantity, by "squeezing" all the noise energy from an event into a one-second period. The SEL is often used to quantify sound from aircraft flyover events. **Figure 1-2** (taken from FAA literature) provides a graphical example of the SEL compared to the equivalent sound level (essentially the time-averaged sound level, noted as L_{eq}) and the L_{max}.

Figure 1-2: SEL, L_{eq}, and L_{max} Compared for the Same Event



In the example shown, the plot shows a time history of sound levels over many seconds, as measured at a fixed microphone location. Some event caused sound levels to rise, reach a maximum, and then fall back down to the background sound level. The "beginning" of the event occurs when the sound level is 10 dBA below the maximum. The event ends after sound levels have dropped to 10 dBA below the L_{max}. The SEL is the value that would result had the event occurred within a 1-second period (instead of 5 or 10 seconds).

Because the averaging period is 1 second, and not the 10 or 20 seconds it took for the event to occur, the SEL is typically a larger value than the maximum level (L_{max}) for the event. For example, a 1-second noise event resulting in 80 dBA (L_{max}) would result in an SEL of 80 dBA (same as L_{max}). However, if the 80-dBA event had lasted 2 seconds, the SEL would be 83 dBA.

The SEL is sometimes preferred over L_{max}, because measurements can be repeated with greater reliability. In addition, the duration of the transient sound is incorporated into the SEL value, which is often important when predicting subjective response. The exact maximum level of a transient event can change depending on sound propagation conditions and other variables, whereas the SEL is a bit more repeatable.

1.3.3 Effects of Noise

Environmental noise, including noise from vehicles, aircraft, and other anthropogenic sound sources, is an important factor for quality of life. The Federal Highway Administration notes that, "studies have shown that some of the most pervasive sources of noise in our environment today are those associated with transportation. Traffic noise tends to be a dominant noise source in our urban as well as rural environment." Long-term exposure to high sound levels has been shown to increase stress levels and reduce health in exposed persons.

The Environmental Protection Agency (EPA) developed guidelines for environmental sound levels in their 1974 document "Information on Levels of Environmental Noise Requisite to Protect Public Health and

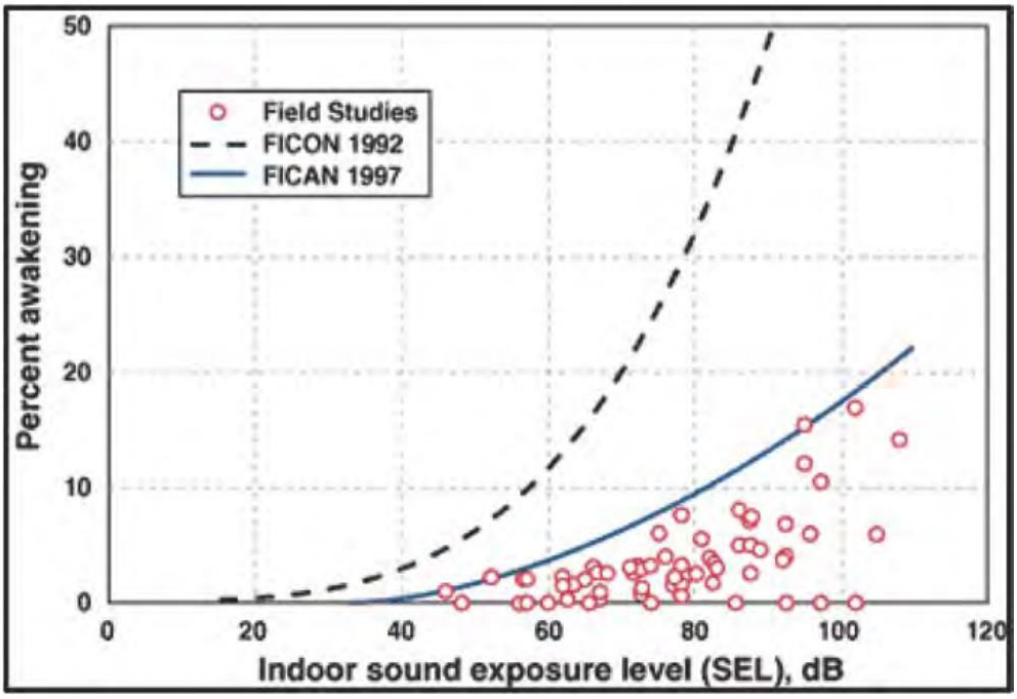
Welfare With an Adequate Margin of Safety". The EPA recommends a maximum L_{dn} of 55 dBA for outdoor residential areas. The L_{dn} is a 24-hour average sound level with a 10-decibel penalty applied to sounds generated during the nighttime hours of 10:00 pm to 7:00 am.

The American National Standards Institute (ANSI) has a multi-part standard regarding environmental noise. ANSI/ASA S12.9-2007/Part 5 (R2017) assesses the "compatibility" of land use types with the outdoor noise environment based on the L_{dn}. An L_{dn} of 45 to 55 dBA is considered compatible with single-family, urban/suburban residential areas with extensive outdoor use, and an L_{dn} of 55 to 57.5 dBA is considered marginally compatible.

The EPA and ANSI environmental noise guidance has been developed as a way to quantify the effects of long-term environmental noise and uses 24-hour average sound levels as the metric for evaluation. Many of the excessive vehicle noise complaints are not related to long-term average traffic sound levels, but rather focus on a few short-term loud events from a few noisy vehicles. The SEL is a better sound level metric for evaluating disturbances from short-term transient noise sources.

The Federal Interagency Committee on Aircraft Noise (FICAN) has researched sleep disturbance dose-response, as a function of the indoor SEL. The Indoor SEL is used to predict the maximum percent of the population expected to be awakened (or the "maximum percent awakened"). FICAN updated its recommended sleep disturbance dose-response curve in 1997, depicted as the lower curve in **Figure 1-3**.

Figure 1-3: Chance of Sleep Disturbance Compared to SEL



The curve shows the percentage of subjects awakened by aircraft noise events, as a function of the indoor sound exposure level (SEL) in dBA. The data in **Figure 1-3** are based on the results of three field studies and datasets from six previous field studies.

The solid blue curve represents the higher end, or upper envelope of the field data. The solid blue curve envelope can be interpreted as predicting the maximum percent of the population expected to be awakened

(or the “maximum percent awakened”) for a residential community under investigation. For example, three percent of people would likely be awakened at an indoor SEL of 60 dBA, which is equivalent to an outdoor SEL of 75 dBA, assuming 15 dBA noise level reduction from outdoor to indoor with windows open.

1.4 Report Organization

The sections that follow this introduction are as follows:

- **Section 2** summarizes current vehicle noise legislation in Vermont. This section also discusses the current state of noise-related sections of the Vermont Automated Vehicle Inspection Plan (AVIP) and the Vermont Periodic Inspection Manual (PIM).
- **Section 3** summarizes current technologies and standards for measuring vehicle sound levels.
- **Section 4** addresses the five study topics outlined in the legislative charge. Each subsection covers an individual topic.
- **Section 5** introduces new and emerging technologies that may address some of the challenges associated with enforcing vehicle noise statutes.
- **Section 6** provides findings for consideration by the legislature as it considers how to move forward.

2.0 Current Vermont Vehicle Noise Regulations

This section describes relevant State and Local regulations in Vermont pertaining to motor vehicle noise and muffler requirements. Also included is a discussion of the Vermont Periodic Inspection Manual (VPIM) exhaust system examination procedure. Neither the regulations nor the VPIM include a quantitative noise limit or a method for measuring noise levels emitted by a vehicle.

2.1 Vermont State Statutes

The relevant sections of the current Motor Vehicle Laws of Vermont (2022 edition):

Vermont Statutes Annotated Title Twenty-Three. Motor Vehicles.

Chapter 1. General Provisions

(37) "Standard equipment" and "properly equipped" as applied to a motor vehicle shall include adequate tires, head lamps, tail lamps, lenses, reflectors, brakes, muffler, rear view mirror, windshield wiper, horns, windshield, number plate brackets, and only such motor fuel tank or tanks as are regularly installed by the manufacturer.

Chapter 13. Operation of Vehicles

Subchapter 14. Equipment

Article 1. General Requirements

1221. Condition of vehicle

A motor vehicle, operated on any highway, shall be in good mechanical condition and shall be properly equipped.

1222. Inspection of registered vehicles

(b) (1) The inspections shall be made at garages or qualified service stations, designated by the Commissioner as inspection stations, for the purpose of determining whether those motor vehicles are properly equipped and maintained in good mechanical conditions; provided, however, the scope of the safety inspection of a motor vehicle other than a school bus or a commercial motor vehicle shall be limited to parts or systems that are relevant to a vehicle's safe operation, and such vehicles shall not fail the safety portion of the inspection unless the condition of the part of the system poses or may pose a danger to the operator or to other highway users.

Essentially, the current Vermont motor vehicle laws related to noise are limited to ensuring that all vehicles are in good mechanical condition and properly equipped with a muffler. The inspection guidance limits the scope of the inspection to "parts or systems that are relevant to a vehicle's safe operation". There are no objective standards or quantitative methods in the law to define good mechanical condition, other than referring to "as installed by the manufacturer".

2.2 Local Ordinances in Vermont

Several municipalities in Vermont have adopted their own vehicle noise ordinances. The text of the applicable sections of these ordinances is included in **Appendix A**, and the text is summarized in **Table 3**. In general, the ordinances are similar to the Vermont state statute, in that they require a muffler "in good working order". Several of the ordinances are more explicit than the State Statute, in that they limit changes to mufflers by forbidding removal, damage, or modification to the baffles in a muffler and disallowing a muffler cutout, bypass, or similar device on a muffler. Saint Albans is the only ordinance that includes a sound level assessment by specifically banning any muffler cutouts, whistles, or muffler removal that cause *the motor vehicle to be audible at a distance of 50 feet*.

None of the existing local ordinances in Vermont include a specific noise level limit or call for any type of noise testing or certification. There is an implied visual inspection component to the ordinances, in that many prevent the removal or modification to the exhaust system. However, there is no codified requirement for inspection of vehicles. This would imply that the enforcement of the ordinances is left largely to the discretion of local law enforcement.

Stakeholders noted that, in their experience, there is limited enforcement of these ordinances due to the challenges discussed in Section 4.1.3.

Table 3: Summary of Local Noise Ordinances in Vermont

Locality	Summary
Burlington	Muffler required in good working order. Modifications to exhaust system unlawful if vehicle would "make a louder noise than it would have in its original condition".
Bennington	Muffler required in good working order. No removal, damage to muffler allowed - no cutouts or bypasses allowed
Woodstock	Same text as Bennington
Enosburg Falls	Similar text to Bennington / Woodstock
Alburgh	Muffler required which "effectively prevents loud or explosive noises"
Williston	Same text as Alburgh
West Windsor	Prohibits "abnormal engine, exhaust, or tire noise"
Putney	Prohibits "discharge into the open air of the exhaust". Muffler required which will "effectively precent loud or explosive noises".
Rutland	Prohibits modifications that increase the sound level above the original manufacturer
Springfield	Same text as Alburgh
St. Albans	Muffler required in good working order. Unlawful to have a cutout, exhaust whistle, or no muffler if the vehicle is plainly audible at 50 feet.

2.3 Vermont Periodic Inspection Manual

2.3.1 Overview

The Vermont Periodic Inspection Manual (VPIM) is the primary guidance document for official inspection station owner/operators and certified inspection mechanics on the procedures and standards used for vehicle inspections in Vermont. The current version of the VPIM became effective on January 1, 2020.

The VPIM was extensively edited and revised in 2019, with the goal of simplifying and clarifying the inspection process. Stakeholders noted that the 2019 revision of the VPIM reduced the length of the VPIM from more than 500 pages to its current length of 159 pages. This was accomplished by removing large sections of the VPIM that did not directly relate to the safe operation of the vehicle.

The primary purpose of the inspection process is to Pass or Reject a vehicle, per the VPIM procedures. While the VPIM was being revised by a committee of experts and professionals, they identified criteria deemed not critical to safe vehicle operation but still relevant to the inspection process. To address this, the new manual includes an "Advisory" category (in addition to Pass and Reject), designed to inform and educate the customer about a recommended repair or potential violation of the law. A vehicle cannot fail an inspection due to "Advisory" notes.

The VPIM contains no methodology for quantifying sound levels (in decibels, dB) emitted by a vehicle. The manual does not consider noise as critical to safe vehicle operation. Therefore, the VPIM contains no procedure requiring measurement of noise emission or rejection of a vehicle due to noise. Implementation of such a mechanism, such as incorporation of noise testing, would require a Rule change to the VPIM. Noise testing would also require new equipment, training, and changes to the Automated Vehicle Inspection Program (AVIP)/Tablet software.

2.3.2 Noise in the Current VPIM

Noise is mentioned in four locations in the current VPIM, relating to the examination of car and light truck exhaust systems, engines, brakes, with the fourth mention relating to motorcycle exhausts. Of these, only two mentions refer to vehicle noise emitted as a nuisance. The first of these is in the exhaust system inspection section for cars and light trucks:

> Vermont Periodic Inspection Manual: PLEASURE CAR AND LIGHT TRUCK
>
> **EXHAUST SYSTEM**
>
> Procedure: Examine vehicle exhaust system and components, including piping leading from the cylinder head to the exhaust end of the tailpipe.
>
> **Reject** vehicle if:
>
> 1. The vehicle has no muffler.
>
> 2. There are non-manufactured holes or leaks in the exhaust system from cylinder head to the tailpipe.
>
> Note: Repairs with equal or greater material than that commonly used in the manufacturing of exhaust systems are permitted.
>
> 3. Components of the system are not securely fastened.

4. Any heat shield connected to the body (floor pan) is missing.

5. Any component of the system passes through the passenger compartment.

6. The exhaust system does not discharge exhaust fumes beyond the passenger compartment of the vehicle.

Advise customer if:

1. The tailpipe end is pinched, plugged, or crushed, which would restrict the exhaust flow.

2. If any heat shield connected to the exhaust system (not to the body/floor pan) is missing.

3. There is a muffler, muffler cutout, or similar device that **allows excessive noise**. (*ed: emphasis added*)

The second such mention of noise in the VPIM is in the exhaust section for motorcycles:

EXHAUST SYSTEM

Motorcycles, motor-driven cycles, and autocycles must be equipped with an exhaust system, where applicable, incorporating a muffler or other mechanical device for the purpose of reducing engine noise.

Procedure: Examine the complete exhaust system, paying particular attention to rusted and corroded parts and surfaces.

Reject vehicle if:

1. The muffler or exhaust pipe has breaks, open seams, or perforations. All joints must be tight, and the entire system must be firmly attached to the vehicle.

2. Any patch or repair jacket is used other than one welded securely and completely around the entire perimeter.

3. Any component is not securely fastened or is located, so it interferes with the operation of the motor-driven cycle.

4. Shielding is not present to prevent inadvertent bodily contact with any part of the exhaust system during normal operation.

5. Any muffler (or catalytic converter, if so equipped) is present that is not original factory installed equipment, not equivalent replacement equipment, or not designed for highway use.

6. The muffler does not have baffles or baffles have been removed.

7. Any changes, modifications, alterations, deletions, or adjustments have been made to the exhaust system that would cause any exhaust system to generate **an unreasonable sound level**. *(ed: emphasis added)*

Advise owner if:

1. The exhaust system has cutout or bypass in violation of 40 C.F.R. 205.166.

Currently, the VPIM requires inspection mechanics to “Advise” passenger vehicle and light truck owners if there is a muffler, muffler cutout, or similar device that causes excessive noise. Inspection mechanics are required to “Reject” a motorcycle if there have been any changes or modifications to the exhaust system that would cause it to generate an unreasonable sound level.

A stakeholder in the interview process noted that, in their opinion, including exhaust changes in the "Reject" category for motorcycle inspections was a clerical error made by the committee when rewriting the VPIM in 2019. In the stakeholder's opinion, the intent of the committee was to include this as an Advise rather than Reject.

There is no definition or objective standard in the VPIM for what might be deemed an excessive or unreasonable sound level. This would place the full determination of the need to issue an Advise notice for passenger vehicles and light trucks or a Reject notice for motorcycles at the discretion of the inspection mechanic.

2.3.3 Noise as a Safety Issue

The VPIM does not consider noise from passenger vehicles and light trucks to be a vehicle safety issue. The VPIM revision committee determined that noise emission was not critical to the safe operation of the motor vehicle. As outlined in the current statute defining state inspections, vehicles are only rejected on the basis of the safe operation of a vehicle.

2.3.4 Limitations

The inspection process may not prevent the use of after-market or modified exhaust systems, as they can be swapped with the original manufactured exhaust system to pass inspection and reinstalled post inspection.

2.4 Commercial Vehicles

Currently, Commercial Motor Vehicles (CMV) in Vermont are regulated by the Department of Motor Vehicles (DMV) Enforcement & Safety Division. The DMV performs annual vehicle inspections on all CMVs. The DMV also conducts pop up inspections along rural routes and interstates, to spot check CMVs for compliance with the various Vermont DMV requirements. Both types of inspections include a visual inspection of exhaust system components by the inspector. There are currently no quantitative noise requirements or noise testing in CMV inspections.

3.0 Vehicle Noise Level Measurement Technologies

3.1 Overview

The enforcement of a vehicle noise statute with a specific absolute sound level limit would require some method for the objective measurement of vehicle noise levels. In order to be consistent, legally defensible, and objective, noise measurements must:

- use standardized equipment for collecting the measurement;
- be performed using a standardized methodology, which is consistent across testing locations;
- account for background noise (noise from sources other than the vehicle under test);
- include training and / or certification for the individuals performing the testing;
- allow for the documentation of measurement results; and
- include some methodology for the consistent calibration and validation of the measurement equipment.
- consider potential scrutiny from the courts

3.2 Measurement Standards

The Society of Automotive Engineers (SAE) has developed many standards for the measurement of vehicle noise. The purpose of each standard is to define the equipment, environment, and test procedures required to measure the sound levels of both stationary and accelerating vehicles and motorcycles. Each standard typically covers a single vehicle category and use case, such as stationary, accelerating, or pass-by noise levels. Relevant standards are listed below.

-SAE Standard J1169 - Measurement of Light Vehicle Exhaust Sound Level Under Stationary Conditions {J1169_200707 *Cancelled* - This standard has been cancelled by the SAE and superseded by J1492.

-SAE Standard J1492 - Measurement of Light Vehicle Stationary Exhaust System Sound Level Engine Speed Sweep Method {J1492_202311} *Current*

-SAE Standard J2805- Measurement of Noise Emitted by Accelerating Road Vehicles {J2805_202005} *Current*

-SAE Standard J1470- Measurement of Noise Emitted by Accelerating Highway Vehicles {J1470_202308} *Stabilized*

-SAE Standard J1287- Measurement of Exhaust Sound Pressure Levels of Stationary Motorcycles {J1287_201704} *Revised*

-SAE Standard J2825- Measurement of Exhaust Sound Pressure Levels of Stationary On-Highway Motorcycles {J2825_202007} *Reaffirmed*

-SAE Standard J331- Sound Levels for Motorcycles {J331_202007} *Reaffirmed*

-SAE Standard J1074- Engine Sound Level Measurement Procedure {J1074_201405} *Stabilized*

3.3 Sound Level Meters

A Sound Level Meter (SLM) is a device capable of measuring the sound pressure level. There are a wide range of commercially available SLMs, from simple meters that can only record a single value, such as the overall A-weighted sound level (dBA), to sophisticated SLMs that include real-time analyzer capabilities – allowing the simultaneous measurement of hundreds of different sound level metrics, including the sound level at octave band center frequencies.

International standards define several overall classes of SLM based on the accuracy and repeatability of the measurements performed by the meter. Generally, commercially available SLMs are classified as Type 1 or Type 2 meters. Type 1 meters are more accurate and have a tighter tolerance than Type 2 meters. The increased accuracy of Type 1 meters incurs a significantly higher purchase price.

The functionality of SLMs is widely variable, with some meters including Bluetooth or wireless connectivity for data access and storage, GPS for location and time synchronization, cameras, and other advanced features. With this wide range of functionality comes a wide range of pricing, with Type 1 SLMs costs of $2,500 to more than $10,000 per unit. Type 2 meters are significantly less expensive, ranging in cost from $150 to $2,500. **Figure 3-1**and **Figure 3-2** show photographs of a typical Type 1 and Type 2 sound level meter, respectively.

SLMs measure the sound level at the microphone including all sounds in the area. They are not capable of separating the influence of the sound source under test, for instance a motor vehicle exhaust, from other sounds in the area, such as nearby traffic noise or noise from wind or rain.

Figure 3-1: Type 1 Sound Level Meter

Figure 3-2: Type 2 Sound Level Meter

3.4 Drive-by Noise Monitoring Systems

Drive-by Noise Monitoring systems are a stationary solution for monitoring vehicle noise levels. Essentially these are a fixed SLM that is combined with other sensors such as cameras, radar / laser speed sensors, GPS, and a computer or data logger, to create a semi-autonomous noise detection and monitoring solution. Parsons researched two different types of Drive-by Noise Monitoring system: Roadside and Station-Based.

Roadside systems require a fixed location, such as an intersection, or along a major or minor street. Dedicated infrastructure is required, including power and cellular or fixed wi-fi connection. Roadside systems can be run indefinitely or in the short term. These systems typically measure sound levels and trigger some action when a set sound level limit is exceeded. For example, a roadside system could trigger a camera or license-plate reader when a sound level limit is exceeded. This approach picks up other environmental noise, such as other vehicles on the road, at the same time as the vehicle being targeted by the system.

Isolating test results can be difficult to ensure a specific vehicle is creating the noise on public roadways, because the Roadside Noise Monitoring system would identify where the noise originates but not specifically which vehicle is causing the noise. Also note that these systems, left unattended, can be

damaged or stolen. Roadside Noise Monitoring Systems have the ability to send real-time notifications of noise-violating vehicles to law enforcement.

Station-Based Noise Measurement Systems are centralized test facilities used to verify compliance in a standardized environment. They typically require a dedicated, large, indoor facility. These Station-Based systems are generally designed for vehicle certification and involve specialized test tracks or stands to measure noise, vibration, and harshness (NVH). Typically, vehicles pass through the facility one at a time to undergo standardized testing to determine vehicle noise levels.

Figure 3-3 shows a picture of a modern road-side noise monitoring system.

3.5 Acoustic Cameras

There are emerging technologies such as acoustic beamforming (also known as acoustic cameras and acoustic holography) that use an array of several microphones to not only measure the sound level but to also determine the source and location of the sound. This technology is superior to a traditional SLM, as it can reliably separate sound levels from multiple sources. However, this technology is an emerging technology and has only been used in traffic noise enforcement for a few years.

Fundamentally, acoustic cameras allow for the automated detection of loud vehicles while they are in motion. This technology can detect not only excessive engine exhaust noise but also dynamic vehicle noise such as engine braking, studded tires, or car stereo noise – sources which cannot be measured during a static test at a vehicle safety inspection or with a Station-Based system.

Acoustic cameras also allow for the automated source separation of loud vehicles. An acoustic camera can create a video showing the dynamic source of the sound as a colored area overlaid on live video of the street. When combined with a license plate reading camera, the system can automatically identify and log excessive vehicle sound events. The camera can identify the source of the sound and can actually calculate the amount of sound energy coming from that specific source. This effectively isolates noise from one individual vehicle from other vehicles on the street. If the calculated sound level from the source exceeds regulatory limits, the vehicle information and video can be logged for future action.

Acoustic cameras can be used as hand-held devices, similar to a large sound level meter, or as road-side systems including license plate reader cameras and wireless communications. **Figure 3-4** shows a handheld acoustic camera. **Figure 3-5** and **Figure 3-6** show the output from a roadside fixed acoustic camera system. In each case, the camera system has identified a noisy vehicle and indicated the source of the noise using a color gradient or a red dot, respectively.

Figure 3-3: Roadside Sound Level Monitoring System

Figure 3-4: Handheld Acoustic Camera

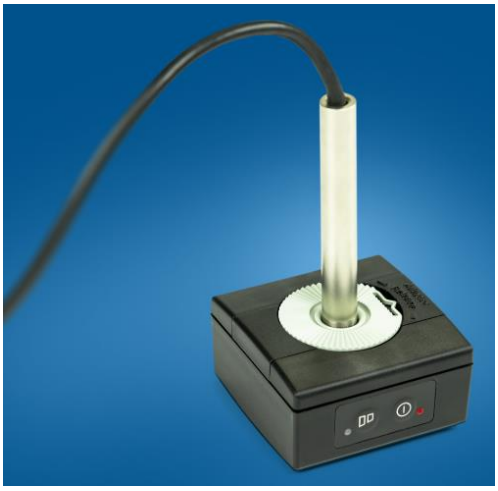
Figure 3-5: Acoustic Camera Imaging Example – Loud car exhaust identified

Figure 3-6: Acoustic Camera Imaging Example – Identifying a loud dump truck exhaust

3.6 Calibration

All of the sound level measurement systems discussed in this report use some type of microphone to measure the sound pressure. Microphone sensitivity can change over time, so devices need to be field calibrated before daily use and laboratory calibrated on a set schedule, typically annually or bi-annually. Field calibration is typically performed using a specifically designed device called a calibrator. Calibrators are classified as Type 1 or Type 2, in similar fashion to SLMs, with Type 1 calibrators suitable for use with Type 1 SLMs. Type 2 calibrators are suitable for use with Type 2 SLMs. Each SLM or measurement device would need a regular field calibration and a set laboratory calibration schedule. During laboratory calibration the device has to be sent to a calibration laboratory for a full function check and recertification. **Figure 3-7** shows a typical Type 1 calibrator and microphone during calibration.

Figure 3-7: Calibrator and Microphone



3.7 Integration into the AVIP / VPIM

Parsons is the developer and maintainer of the Vermont AVIP system. Parsons developed an evaluation of the steps necessary to integrate sound level testing into the AVIP. They assessed SLMs (SLMs) and drive-by systems. They assumed that the SLM approach would entail using existing facilities, with SLMs used as part of the current inspection process. For the drive-by option, they assumed that stand-alone, dedicated indoor facilities would be used.

Parsons determined that there are SLMs which can communicate directly with existing the AVIP Inspection Tablets, via Bluetooth technology. This would make it possible to send noise emission data collected with SLMs to the Vehicle Inspection Database (VID). This process would require some software changes, but it would not require major changes to the overall AVIP/Tablet/VID infrastructure. The software development would entail a set of guided instructions for the Inspection Mechanic, with new screens and prompts needed to properly perform the noise test. The new vehicle noise testing system would then need to undergo a pilot program, using pilot stations already part of AVIP. Costs associated with software development are described in Section 4.2.1.

Parsons determined that a station-based drive-by noise monitoring system would require significant change to the AVIP infrastructure. It would also require much more equipment than just SLMs. The

station-based approach would be significantly more complicated than pairing a hand-held sound meter with the Tablet/VID system.

4.0 Legislative Topics

The following sections address the five topics included in the legislative language in Section 42, restated below:

1. If there should be a noise standard in statute or the Periodic Inspection Manual (PIM), or both, and, if so, what that standard should be; (**Section 4.1**)

2. Costs to incorporate noise testing into the PIM; (**Section 4.2**)

3. Costs to train law enforcement officers on noise testing; (**Section 4.3**)

4. Possible options to address excessive motor vehicle noise not involving noise testing (visual inspections, enforcement of the State motor vehicle inspection, and labeling of components of exhaust system components); (**Section 4.4**)

5. Approaches to minimize excessive motor vehicle noise from other states (increased enforcement by law enforcement coupled with an objective noise standard) (**Section 4.5**)

4.1 Noise Standard in Statute or VPIM

This section addresses the first legislative charge:

> (1) if there should be a noise standard in statute or the Periodic Inspection Manual, or both, and, if so, what that standard should be;

4.1.1 Overview

The question of whether there should be a noise standard in statute or as part of the VPIM is very complex. Noise standards which are objective / quantitative limit the sound level produced by a vehicle, whereas standards that are subjective / qualitative require a subjective assessment of whether the noise from a vehicle is typical or excessive. Presumably, a subjective assessment would be informed by previous experience and observations. In theory, a noise standard in statute or as part of the VPIM could be implemented in a few ways:

- An objective / quantitative statute could be adopted that would create a numerical vehicle noise standard, i.e. a maximum vehicle sound level under some standardized condition. The statute would presumably be enforced by law enforcement personnel through a standardized test procedure using standard equipment.
- A subjective / qualitative statute could be adopted which expands the ability of law enforcement personnel to make subjective assessments as to reasonableness of the noise emitted by a vehicle or to assess the presence of certain required equipment. This would be enforced through traffic stops based on a judgement call.
- The VPIM could be updated to include either an objective vehicle noise standard, presumably verified during the vehicle's inspection through a noise test, or through a visual inspection of

vehicle components during the inspection procedure. Either of these would depend on vehicle inspection mechanics to enforce the noise standard or to perform the visual inspection, and any decisions or judgement calls would be at the discretion of the individual inspection mechanic.

A statute intended to place a quantitative limit (in decibels, dB) on noise emission needs to be reasonable, easily interpreted, and easily enforceable. Human reaction to noise is subjective, so a limit deemed reasonable by some may not be considered reasonable by others. Some might consider the limit too restrictive or not restrictive enough.

In all cases, parties responsible for interpreting or enforcing a noise statute must be provided with proper equipment and training. Training must include proper use of sound measurement equipment, as well as training on methods for interpreting measurement results.

Section 2.3 previously described noise standards in the current VPIM, which does not contain any quantitative methods or standards for assessing vehicle noise.

4.1.2 Types of Noise Standards

Generally, vehicle noise standards fall into two broad categories: visual-inspection-based standards that are enforced during state-mandated vehicle inspections; or noise limits for vehicles that are enforced by law enforcement or inspection mechanics using some form of noise testing. Inspection-based regulations typically require that vehicle inspection mechanics either visually inspect a vehicle's exhaust system and make a visual determination of its fitness, or that they make a qualitative determination that changes to the vehicle's exhaust would make it louder than the original manufacturer equipment.

Noise testing typically requires the use of a SLM, used in accordance with a written procedure for quantifying vehicle noise emission at some distance and operating condition (stationary or moving).

4.1.3 Stakeholder Feedback

Stakeholders had mixed opinions about the need for a noise standard in Vermont statute or in the VPIM. Generally, feedback was against the need for a noise standard in statute or in the VPIM, due to the difficulty of implementing a noise standard and concerns about allocation of limited resources for enforcement.

Stakeholder responses included:

- Observations that noise is not a high priority for the stakeholder's constituents
- Concerns about the need to dedicate limited resources to noise enforcement that would be better spent on other traffic safety issues such as excessive speed or DUI enforcement
- Concern about the arbitrary nature of some noise standards that reference "excessive" or "unusual" noise levels. There were consistent concerns about any noise standard that would require a judgement call from law enforcement or inspection mechanics. Stakeholders noted that judgement calls or non-quantitative enforcement requirements are not compatible with current guidelines for traffic enforcement. Several stakeholders pointed out that there has been a general trend to reduce traffic stops and traffic enforcement, with significant reductions in the

number of traffic stops across the state over the last several years. There was concern about the legal implications of law enforcement discretionary stops based on noise.

- Concerns about adding additional responsibilities onto law enforcement personnel, such as the training required to use SLMs and methodology for standardized noise testing
- Difficulty in accurate / repeatable / defensible noise testing
- Concerns about adding additional steps to the VPIM. Stakeholders noted that the VPIM was reduced in scale and scope significantly in 2019, and adding a noise requirement would reverse that work to some extent
- Concerns that noise testing during an inspection might impose additional costs on Vermont residents
- Concerns that visual inspections by law enforcement personnel are not practical, as personnel cannot be expected to climb under vehicles during traffic stops to investigate the presence of required equipment.
- Concerns that visual inspections by inspection mechanics may be too subjective and lead to inconsistencies in the inspection process.

Some stakeholders expressed support for a noise standard in statute or in the VPIM. These stakeholders often referenced personal experiences with loud vehicles close to their residences or in their neighborhoods. They also referenced anecdotes about noise as a negative environmental impact and referenced the presence of a few loud vehicles or a small number of significant offenders.

Generally, stakeholders, even those from the law enforcement community, did not have specific experience with traffic noise enforcement or noise measurement.

4.1.4 In Statute

Implementation of a noise standard in statute would likely require significant effort and coordination across a wide range of disciplines. Any quantitative noise regulation would require extensive research, outreach, and full consideration of legality, reasonableness, enforceability, and cost.

A noise standard implemented through statute would, presumably, require active involvement from law enforcement (State and Local) towards enforcing any Statewide standard. This would require purchase of SLMs, officer training, and development of new procedures. It may be possible to eventually offset SLM and training costs by way of fines/tickets, but that would require further analysis. Very stringent legislation might consider a complete ban on aftermarket exhaust systems, though the legality of this would likely be challenged.

Some states (see Section 4.5) prohibit any aftermarket exhausts that emit higher noise levels than the original equipment installed by the vehicle manufacturer. However, measuring and/or quantifying this in any rigorous way could be difficult (see Sections 4.1.6 and 4.1.7).

4.1.5 In the VPIM

Implementation of a noise testing requirement in the VPIM would require a Rule change to the VPIM (Administrative Procedure Act, APA). As a purely administrative process, a VPIM rule change would

require between 6 and 8 months to include time for filing paperwork; testimony in front of the Interagency Committee on Administrative Rules (ICAR); hosting a public hearing (documenting and recording comments); and testimony before the Legislative Committee on Administrative Rules (LCAR).

A VPIM change would also include the development of a standard methodology for measuring and quantifying vehicle noise, with a focus on exhaust measurements. Inspection mechanics would require training and education in how to properly conduct noise testing, per applicable SAE methods. Testing facilities would then need to be equipped with measurement equipment (SLMs), and the SLMs would have to be integrated with the AVIP/Tablet/VID infrastructure.

4.1.6 Challenges – Roadside Law Enforcement

About 10 states, including Rhode Island, Connecticut, and Maine, have quantitative vehicle noise limits, such as those based on a sound level (in dB) measured at some distance from the moving vehicle under investigation. Enforcement measurements are typically made in an uncontrolled setting, such as by the side of a roadway or in a parking lot. There are many challenges inherent to enforcing such a standard, including weather conditions, site selection, ambient noise contamination, and equipment limitations.

Outdoor sound measurements pose a series of challenges, particularly if the weather is uncooperative. Assuming vehicle noise enforcement were to occur in a manner similar to vehicle speed enforcement, weather conditions would have to be fairly good to collect defensible sound readings. Readings cannot be conducted during rain, snow, or when roadways are wet. Furthermore, wind speeds must be fairly light and variable.

The location chosen to conduct measurements must be fairly level, devoid of major obstacles, and not likely to cause driver distraction. There cannot be other nearby sources of noise (commercial businesses, HVAC equipment, etc.).

Sound measurement equipment must be properly calibrated before and after each use, and the procedure would need to conclusively determine that measured sound levels are attributable to the vehicle in question. At high speeds, this could be very challenging, even if sound measurements were coupled with video recordings of the vehicle. If there are other vehicles present, such a determination may be next to impossible.

There is a high potential that measured sound levels would not conform to widely accepted engineering standards, which could potentially result in dismissal in a legal setting.

These challenges would exist whether the sound measurements were conducted by an officer, or if they were conducted with a drive-by monitoring system (see Section 3.4).

In summary, the challenges to vehicle noise testing as enforced by law enforcement are:

- Difficult to test noise on the side of road
- Difficult to determine the appropriate sound level limit
- Law enforcement must make a subjective determination of which cars to test
- Only subjectively noisy vehicles are tested, so some noisy vehicles may be missed

- Additional demand on limited law enforcement resources - diverts traffic stop attention away from speed / DUI / other safety enforcement, and
- Law enforcement may not use equipment or implement noise testing due to other obligations.

Potential benefits from this method:

- Implements an objective standard,
- Testing can be performed while vehicle is in motion, to detect vehicle noise such as engine braking noise, loud stereos, etc., and
- Testing occurs on vehicles as they are driven, not during a scheduled test - this eliminates owners removing aftermarket mufflers before inspections.

The majority of stakeholders expressed concerns about diverting limited law enforcement resources to noise testing, rather than other safety-related traffic issues such as speed or DUI enforcement. There were concerns that law enforcement would not use the supplied SLM equipment, or that they would use it so rarely that training would be forgotten and procedures not followed.

Several stakeholders expressed concerns that there would be legislative challenges to the use of unattended roadside systems in Vermont due to state requirements that: 1) law enforcement identify the operator of the motor vehicle rather than the owner during issuance of a citation, and 2) law enforcement must issue the ticket, rather than a third party. Stakeholders understood that these limitations made devices such as speed cameras, red light cameras, or other automated systems impractical in the State of Vermont.

A stakeholder noted that there was active legislative research into the use of automated speed cameras in Vermont. The research from this working group will likely include the necessary legislative and legal framework to pursue unattended roadside system use in Vermont, as the required changes should be similar for speed enforcement and noise enforcement systems.

4.1.7 Challenges – Inspection (VPIM)

Vehicle noise testing through the inspection process (VPIM) could potentially be more accurate than outdoor roadside testing, but there are still many challenges. The focus would be limited to exhaust noise. Most notably, inspections through a VPIM process may not prevent the use of after-market or modified exhaust systems. Such systems can be temporarily replaced with the original manufactured system to pass inspection and then reinstalled after inspection. A VPIM noise testing approach assumes that the exhaust system under investigation (presumably an Original Equipment Manufacturer, OEM system), will not then be swapped out after the “PASSED” vehicle leaves the inspection facility. Methods for possibly addressing this (labeling) are discussed in Section 4.4.

Indoor noise testing in a garage setting, intended to quantify noise emission from a specific source or piece of equipment (muffler, exhaust), requires that the measurement not be corrupted or contaminated by other nearby noise. For example, other noises such as shop vacuums, pneumatic wrenches, etc. must not influence the testing. This could be very difficult to avoid in a repair facility. In other states with noise testing during inspection, the vehicle is typically moved to a quieter test location, such as a nearby parking lot or other open area, for noise testing.

Testing requires that controls and steps be taken to minimize contamination, such as reserving a dedicated area or bay for exhaust testing. The operator must then be properly trained on how to perform the measurements, considering engine operation, microphone orientation, and various other variables. Without proper controls and procedures, testing could result in "false positive" readings, potentially resulting in an improper "Reject" finding in the inspection.

In summary, the challenges for adding vehicle noise testing to the VPIM are:

- Must be conducted on all vehicles - not just noisy ones,
- Difficult to determine the appropriate sound level limit,
- Difficult to test noise in a shop environment,
- Inspection stations may need to find alternative test locations,
- Additional equipment required,
- Inspection stations may not be willing to incur additional equipment costs,
- Additional time and cost for Vermont residents during inspections,
- Will not detect noise that typically occurs while a vehicle is in motion, such as engine braking noise, loud stereos, etc.
- Low efficacy - vehicle owners can remove aftermarket mufflers before inspections and then reinstall them after passing inspection, and
- Recurring annual costs due to SLM maintenance and calibration.

The potential benefits of adding vehicle noise testing to the VPIM are:

- Implements an objective standard,
- All vehicles are tested, and
- No additional burden on law enforcement.

Stakeholders noted that other states, such as Maine, may allow for noise testing to be used as a defense should a person served with a traffic ticket for excessive noise wish to contest the ticket. There are about ten volunteer sound pressure testing stations in Maine. These stations are specifically outfitted to perform noise testing in a controlled environment.

4.1.8 Challenges – Visual Inspection

As with vehicle noise measurement testing, visual inspections through a VPIM process face several challenges:

- Affects all vehicles - not just noisy ones,
- Adds a step to the inspection process,
- May lead to failure for aftermarket or non-OEM exhausts or components which do not increase noise levels,
- May limit Vermont consumers' ability to use aftermarket or non-OEM parts,

- Requires inspection mechanics to make a judgement call on excessive noise and/or aftermarket status of equipment,
- Low efficacy (as with testing) - vehicle owners can remove aftermarket mufflers before inspections and then reinstall them after passing inspection,
- Subjective - does not have an objective / quantitative limit,
- Will not detect vehicle noise due to motion such as engine braking noise, loud stereos, etc.,
- Inspection stations could unscrupulously recommend unnecessary repairs to consumers, and
- Law enforcement officers may have difficulty properly describing an excessive noise determination in a court setting

The potential benefits of adding visual inspections to the VPIM:

- Ease of implementation;
- Low cost and no recurring cost;
- Uses existing inspection system.

Stakeholders noted that there was hesitance in adding a subjective or judgement call element to the inspection process. Stakeholders felt that this was forcing enforcement responsibilities onto vehicle inspection mechanics for an issue which was not considered safety critical.

Visual inspections performed in the field (roadside) by dedicated inspection mechanics or law enforcement could also face many challenges. The process first requires that the law enforcement officer has reasonable justification for conducting the inspection which introduces a judgement call. As a practical matter, roadside visual inspection is very difficult, or even impossible, at night or during inclement weather. Even during optimal conditions, defects to the muffler or exhaust may not be visible without going under the vehicle, which could raise safety concerns. Inspection of “cut-outs” or the inner components of a muffler would not be possible without special equipment (borescope or inspection camera).

4.1.9 Challenges – Engine Braking

Noise due to engine braking is only generated when the vehicle is in motion and the engine brake is activated. Effective testing of noise levels from such a system would require a standardized measurement procedure for a vehicle passby while decelerating under set conditions. Such testing is possible, however, it is complicated and difficult to perform in the field. Typically, this type of testing is performed at a specialized testing center by a vehicle manufacturer.

4.1.10 Vehicle Sound Level Limits

The Noise Control Act of 1972 established a national policy for improving health and welfare with respect to noise in the environment. The Environmental Protection Agency (EPA) is responsible for enforcing provisions in the Act. The Act established noise emission standards, which can be found in the Code of Federal Regulations (CFR Title 40, Chapter I, Subchapter G, Part 205). All medium to heavy trucks produced after January 1, 1988 must not emit sound levels in excess of 80 dBA at 50 feet (L_{max}). The

same limit applies to most on-road and off-road motorcycles manufactured after 1986. The testing procedure (found in the CFR) assumes that the vehicle is accelerating but is not exceeding 35 mph.

For states with vehicle decibel limits, the limit is typically 86 dBA at 50 feet. This is often qualified as the limit for vehicles "manufactured after 1973". Such standards are typically intended to limit excessive noise from faulty or modified exhaust mufflers. Modern vehicles with functioning mufflers emit significantly lower levels than 86 dBA. Considering this, an 86-dBA limit would generally help to identify "excessively loud" vehicles.

It was shown in Section 1.3.3 that the sound exposure level (SEL) from a single noise event can be used to predict sleep disturbance. However, SEL is not the same as the maximum sound level (L_{max}) during a vehicle passby event. For vehicle speeds of 40 mph the SEL is typically 4 dBA higher than the L_{max}. Using this approximate relationship, an outdoor L_{max} of 86 dBA would correspond to an SEL of approximately 90 dBA. If an outdoor-to-indoor noise reduction of 15 dBA is assumed, the indoor SEL would be approximately 75 dBA. This corresponds to a "maximum percent awakened" of 6 to 8%, per **Figure 1-3**. The 80-dBA limit from the CFR would result in a slightly lower percent awakened of 5 to 6%.

4.2 Noise Testing Costs (State Inspection/VPIM)

This section addresses the second legislative charge:

> (2) costs to incorporate noise testing into the State motor vehicle inspection required under 23 V.S.A. § 1222 and the State's Periodic Inspection Manual;

Costs associated with testing would include purchase of equipment (SLMs), training, or fees charged by inspection shops. Estimated costs are discussed in the following sections. A detailed table of costs and the assumptions used to develop the cost estimates, along with the benefits and challenges for each option can be found in **Appendix B**.

4.2.1 Costs for VPIM Noise Testing (Equipment and AVIP)

Implementing noise testing in the VPIM would first require a Rule change to under the Administrative Procedure Act. APA filing forms are provided by the Office of the Secretary of State for the purpose of filing administrative rules. The entire process to request and implement a rule change to the VPIM is estimated to take between 6-8 months and costs approximately $2,200 and staff time associated with filing paperwork, testimony in front of the Interagency Committee on Administrative Rules (ICAR), hosting a public hearing (documenting and recording comments), testimony in front of the Legislative Committee on Administrative Rules (LCAR) etc.

Noise testing through the VPIM procedure would require that all testing facilities and inspection mechanics have standardized devices for measuring sound. There are currently phone/tablet applications that, when coupled with a microphone, meet Type 2 classifications. Alternatively, traditional SLMs could be used.

Maine inspection mechanics estimated that a SLM and a calibrator that meets the SAE standards was approximately a $300 investment per station. Using a slightly more conservative cost of $500 per station to account for Bluetooth capability (for integration into the AVIP) and inflation, with around 1,100 certified

inspection stations in Vermont, this would be a total state-wide investment of about $550,000 for SLMs and calibrators.

SLMs need to be laboratory calibrated / certified on a regular interval, to ensure that they are sufficiently accurate for use in testing. For a 2-year certification interval, the longest that would be recommended by general practice or standards, half of the SLMs in the state would need to be calibrated each year. At $100 per calibration, this would be an annual recurring cost of $55,000 per year.

SLMs will need to be maintained, repaired, and replaced over time. With a 10-year service life per meter, it would be expected that 10% of the fleet of meters would require repair, service, or replacement for an annual maintenance cost of $55,000.

Stakeholders noted that there had been significant pushback from inspection stations on the requirement to purchase printers for the on-demand inspection stickers. There is concern that requiring the purchase of additional equipment for inspections may be met with strong resistance from inspection stations. Similar to the sticker printers, the state could supply SLMs for station use. This model would shift implementation costs from the station and limit the financial impact on inspection stations or the Vermont public.

In Maine, noise testing is an additional fee and pricing is not regulated, with shops charging what the market will bear. Typical costs range from $35 for a single exhaust to $45 for a dual exhaust. If this model is adopted in Vermont, then stations could recoup the startup and maintenance costs for the SLMs through increased inspection fees. This would essentially pass the cost of implementation on to Vermont vehicle owners.

Another cost associated with implementing noise testing into the VPIM would be the labor costs for changes that will need to be made in the AVIP/Tablet software to support this additional inspection requirement. Vermont's AVIP Vendor, Parsons, estimated an approximate cost of $70,000 to make software changes to the AVIP/Tablet. That estimation factors in about 800 IT hours at a rate of approximately $115 an hour. This estimation is based on 2019 amendment changes reflecting legislative changes regarding the 2016 model year exemption for OBDII testing. Once the manual is reopened, additional changes may be made as well, so that may alter the final cost.

4.2.2 Costs for VPIM Noise Testing (Testing after Citation)

Implementing noise testing after citation in the VPIM would require a Rule change under the Administrative Procedure Act. APA filing forms are provided by the Office of the Secretary of State for the purpose of filing administrative rules. The entire process to request and implement a rule change to the VPIM is estimated to take between 6-8 months and costs approximately $2,200 and staff time associated with filing paperwork, testimony in front of the Interagency Committee on Administrative Rules (ICAR), hosting a public hearing (documenting and recording comments), testimony in front of the Legislative Committee on Administrative Rules (LCAR) etc.

Noise testing through the VPIM procedure would require that some number of testing facilities and inspection mechanics have standardized devices for measuring sound. For the purposes of this report we have assumed that 30 inspection stations would take on the added responsibility for noise testing after

citation. There are currently phone/tablet applications that, when coupled with a microphone, meet Type 2 classifications. Alternatively, traditional SLMs could be used.

Using a cost of $500 per SLM and adding noise testing to 30 certified inspection stations in Vermont, this would be a total state-wide investment of about $15,000 for SLMs and calibrators.

For a 2-year certification interval, the longest that would be recommended by general practice or standards, half of the SLMs in the state would need to be calibrated each year. At $100 per calibration, this would be an annual recurring cost of $1,250 per year.

SLMs will need to be maintained, repaired, and replaced over time. With a 10-year service life per meter, it would be expected that 10% of the fleet of meters would require repair, service, or replacement for an annual maintenance cost of $1,250.

Another cost associated with implementing noise testing after citation into the VPIM would be the labor costs for changes that will need to be made in the AVIP/Tablet software to support this additional inspection requirement. As discussed above, Vermont's AVIP Vendor, Parsons, estimated an approximate cost of $70,000 to make software changes to the AVIP/Tablet.

Additional costs will be associated with training officers about the new noise legislation and the citation rules and procedures. Based on a 30 minute training course for 1,250 officers and approximately $100 spent per training hour in administration and lost time, the one time cost is estimated at $62,500.

Training will also be required for inspection mechanics at the 30 inspection stations chosen to carry out the noise testing. The estimated cost for developing a training video and training materials for the 30 inspection stations is $7,500 for an online training video and a mailer outlining the required training.

4.2.3 Cost for Acoustic Camera Systems

Acoustic cameras would provide the ability to isolate vehicle noise from other sounds in the area. This could be very useful for testing in the environment of a noisy inspection station, as noise testing could take place during other activities. However, this advanced technology comes at a higher cost than standard SLMs. Handheld acoustic cameras cost about $12,000 per unit. If this technology were required for inspection stations, the total statewide startup investment would be significant, at around $1.2 million. Maintenance and calibration costs would also be incurred for these systems.

Costs for roadside stationary acoustic camera systems, similar to a speed camera, are estimated to be about $45,000 per system for the required legislative and rule changes, hardware, installation, and software development, assuming the implementation of 10 systems, for a total cost of $450,000. The per system cost would increase somewhat if fewer systems were implemented.

Recurring costs for stationary acoustic camera systems would include power, maintenance, and associated costs, and are estimated at $36,000 per year for 10 systems.

4.3 Costs for Training Law Enforcement

This section addresses the third legislative charge:

(3) costs to train law enforcement officers on noise testing;

4.3.1 Law Enforcement Noise Testing (Training)

There would be training costs associated with roadside enforcement using SLMs. Roadside enforcement of visual muffler inspections would also entail some costs, such as training to assist with identification of muffler modifications. It is likely that the training could be performed through interactive online courses.

Law enforcement training would need to cover:

- muffler modifications, cutouts, bypasses for all variations of standard vehicles and motorcycles
- how to use SLMs/ calibration devices
- how to conduct sound testing for vehicles.
- new changes that would be implemented to the VPIM regarding muffler noise, so they are informed on what is needed from them as far as enforcing those laws.

Stakeholders noted that these would be similar to the credentials program created for Pennsylvania.

It is estimated that course development and implementation would cost approximately $15,000.

There are currently 1,016 Level III officers and 201 Level II, IIE, or IIS status officers in the state of Vermont. With about 1,250 officers active in Vermont, 250 officers would need to be trained each year to allow for a 5-year recertification / full-force training schedule. If the cost per training hour is $100, accounting for the lost labor time per officer and for record-keeping and administration, this would cost $25,000 per year in training.

4.3.2 Law Enforcement Noise Testing (Equipment)

Any regulation requiring enforcement by state and local law enforcement would likely involve the purchase of SLMs (SLMs), at a minimum. It is estimated that upwards of 500 sound meters would be needed (200 for state troopers, 300 for local and county officers). The lowest (most conservative) per-unit cost for a precision-grade Type 1 SLM ranges between $2,500 and $12,000. Type 2 SLMs could be suitable for compliance testing and have typical costs of between $150 and $2,500. The SLMs and calibrators used by the State of Maine cost about $300 per unit, including a calibrator. As a conservative estimate, this report uses a per unit cost of $500 per SLM for a total cost of $250,000.

SLMs need to be laboratory calibrated / certified on a regular interval to ensure that they are sufficiently accurate for use in testing. For a 2-year certification interval, the longest that would be recommended by general practice or standards, half of the SLMs in the state would need to be calibrated each year. At $100 per calibration, this would be an annual recurring cost of $25,000 per year.

SLMs will need to be maintained, repaired, and replaced over time. With a 10-year service life per meter, it would be expected that 10% of the fleet of meters would require repair, service, or replacement for an annual maintenance cost of $25,000.

4.4 Alternatives to Noise Testing (Visual Inspection, Labeling)

This section addresses the fourth legislative charge:

(4) possible options to address excessive motor vehicle noise that do not involve noise testing such as visual inspections for modifications to a motor vehicle's exhaust system, whether as part of enforcement of the State motor vehicle inspection, and labeling on one or more components of a motor vehicle's exhaust system;

There are generally a few non-noise testing alternatives. This section discusses visual inspection, labeling, public education campaigns, and road signs.

4.4.1 Visual Inspection

The current VPIM requires a visual inspection of the vehicle's exhaust system for both passenger vehicles / light trucks, and motorcycles. The VPIM could be updated to require inspection mechanics to "Reject" modified, non-OEM, or excessively noisy mufflers for passenger vehicles and light trucks. This would make the inspection process the same for both passenger vehicles / light trucks and motorcycles.

Challenges associated with visual inspections are more fully addressed in Section 4.1.7. Generally, any program including visual inspections could have significant challenges, whether conducted as part of a VPIM inspection (subjective judgement calls required of inspection mechanics, risk of testing swapped-out systems) or roadside actions (officer safety, access, etc.).

Parson's notes that the AVIP inspection application could be modified to require that an Inspection Mechanic look for non-OEM modifications of the tailpipe. The application would leave a non-compliance determination up to the Inspection Mechanic or Law Enforcement in the field. Additionally, the Inspection Mechanic would be required to check on the exhaust and tailpipe emission components and fail vehicles for damaged, weakened, or rusted components.

Stakeholders noted that there was hesitance to add a subjective or judgement call element to the inspection process. Stakeholders felt that this was forcing enforcement responsibilities onto vehicle inspection mechanics for an issue which was not considered safety critical.

4.4.2 Product Labeling

Muffler labeling would utilize a stamp credential, confirming that the muffler under inspection is OEM equipment and achieves acceptable noise levels. The EPA (Environmental Protection Agency) currently uses Vehicle Emission Control Information labels for catalysts. These labels are clearly visible, easily found, and typically have scannable barcodes. The labels confirm that the catalyst complies with the EPA emissions regulations.

A similar label or stamp for the muffler system, if not found during a roadside check, could be grounds for issuance of a violation ticket. However, such muffler noise emission stamps/labels are not currently standard practice. The labeling would have to occur during manufacture of the vehicle.

The EPA does not certify aftermarket products, but the EPA does have a voluntary program for evaluating performance of some aftermarket products, such as fuel additives. This is part of the Aftermarket Retrofit Device Evaluation Program (also called the "511 Program"). The program makes it possible to obtain technical data for aftermarket equipment. Along these lines, it may be possible to have EPA stamps for aftermarket mufflers, showing that the muffler conforms to the EPA noise emission standards (80 dBA at

50 feet, measured per specific EPA test procedures found in the Code of Federal Regulations, Title 40, Chapter I, Subchapter G, Part 205).

Product labeling would seem to require direct coordination between the State of Vermont and vehicle and equipment manufacturers. The potential scale and scope required to implement equipment labeling puts it outside the scope of this report.

4.4.3 Public Education Campaigns

Some have suggested that a public education campaign could have some effectiveness at addressing vehicle noise. This could involve targeted messaging towards people with aftermarket mufflers. Conducting a public education campaign about the impacts of vehicle noise on the health of both individuals and the community in general could potentially reduce vehicle noise issues without noise testing. The campaign could include educational content, helpful tips, and guidance regarding vehicle noise. The information would discuss the purpose of aftermarket exhaust systems and how they may impact vehicle noise, and how such noise might affect neighbors or sensitive individuals. The efficacy of such a campaign would depend on the specific messaging, the medium used to deliver the information, and the scope and scale of the campaign.

4.4.4 Road Signage

Several Stakeholders mentioned the use of road signs requesting trucks to limit the use of engine braking or “jake brakes” in residential or developed areas. Most Stakeholders felt that such signs were generally effective at limiting the noise from engine braking. This was universally acknowledged as the most practical and reasonable method to reduce the impact of engine braking noise on sensitive communities.

4.5 Alternatives from Other States

This section addresses the fifth legislative charge:

> (5) approaches to minimize excessive motor vehicle noise that have been taken in other states, including increased enforcement by law enforcement coupled with an objective noise standard defense.

Current vehicle noise regulations in other states generally fall into two broad categories: visual-inspection-based regulations that are enforced during state-mandated vehicle inspections or noise limits for vehicles that are enforced by law enforcement or inspection mechanics using some form of noise testing. Inspection-based regulations typically require that vehicle inspection mechanics either visually inspect a vehicle’s exhaust system and make a visual determination of its fitness or make a qualitative determination that changes to the vehicle’s exhaust would make it louder than the original manufacturer equipment.

4.5.1 Noise Statutes from Surrounding States

Vehicle noise related statues from nearby states were reviewed as points of comparison. Most of the statutes for mufflers prohibit “excessive or unusual noise”, which are similar to those found in the VPIM and Local Vermont ordinances described in Section 2.2. Some states have quantitative limits, usually measured at 50 feet from the vehicle. **Table 4** summarizes approaches used by nearby states.

Table 4: Summary of Surrounding State Noise Statutes

State	Summary
New Hampshire	Mufflers to be “in good working order” to prevent “excessive or unusual noise”; no straight pipe systems No quantitative noise limit
Maine	Adequate muffler needed to “prevent excessive or unusual” noise; no cutouts, bypass systems. May allow for noise testing to be used as a defense, should a person served with a traffic ticket for excessive noise wish to contest the ticket. There are about ten volunteer sound pressure testing stations in Maine. These stations are specifically outfitted to perform noise testing in a controlled environment. Quantitative Limit: Statute prohibits noise emission above 95 decibels (measured per the SAE J1169 standard). Testing is performed at inspection stations.
Connecticut	Muffler to prevent “unnecessary or unusual noise”; no cutouts, straight pipes. No muffler removal “except to repair or replace the muffler or part for the more effective prevention of noise” Quantitative Limit: Limits moving vehicle noise emission measured at 50 feet based on vehicle age and speed limit zone. Limits range from 72 dBA to 84 dBA at the 50-foot distance, depending on the motor vehicle's speed, weight, and the road surface on which it travels.
Rhode Island	Muffler to prevent “excessive or unusual noise”. Quantitative Limit: Limits moving vehicle noise emission measured at 50 feet based on posted speed limit. Noise limits range from 86 dBA to 90 dBA at the 50-foot distance.
Massachusetts	Adequate muffler needed to prevent unnecessary noise; no cutouts or bypass systems. No quantitative noise limit
New York	Adequate muffler system to prevent excessive noise; no cut-outs, bypass systems Quantitative Limit: Limits moving vehicle noise emission measured at 50 feet based on posted speed limit. Noise limits range from 76 dBA to 82 dBA at the 50-foot distance.

4.5.2 Exhaust Noise Laws Nationally

Most states have prohibitions against mufflers that emit “excessive or unusual” noise.

Seventeen states have an “excessive or unusual” requirement, but they also have prohibitions against modifications to the muffler that would cause noise levels to exceed the original equipment manufacturer (OEM) level. However, not all of these states require or provide an established procedure for measuring the noise levels, meaning that they are subjective and therefore ineffective as an enforcement tool.

Relatively few states (about 10) have laws that involve an objective method for determining or limiting exhaust noise levels. However, this includes states like Connecticut, which has a “measure at 50 feet” standard. As explained in Section 4.1.6, such roadside enforcement standards are very difficult to implement. A few states, like California, have an exhaust noise limit and a required SAE testing procedure. The California language states:

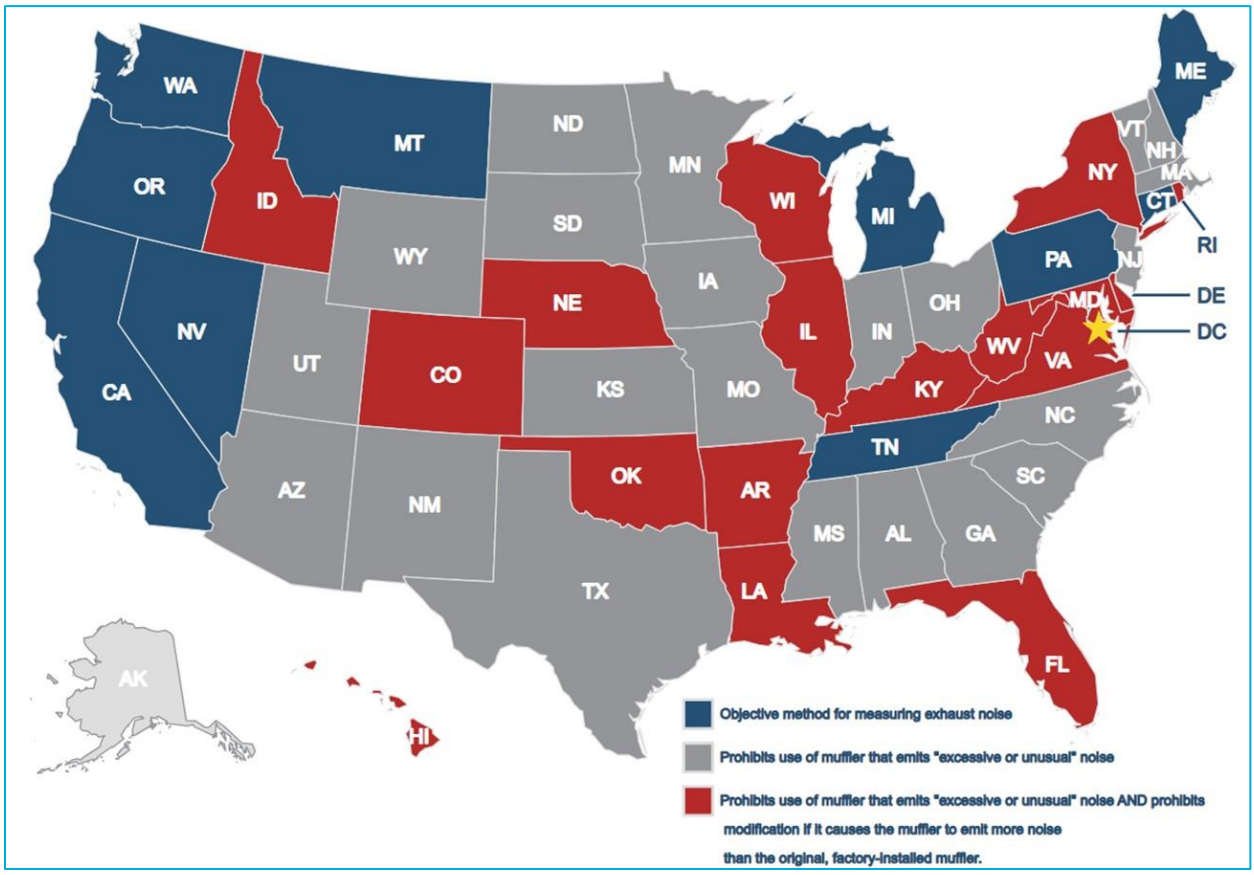
> For the purposes of exhaust systems installed on motor vehicles with a manufacturer’s gross vehicle weight rating of less than 6,000 pounds, other than motorcycles, a sound level of 95 dBA or less, when tested in accordance with the most current SAE International standard, complies with this section. Motor vehicle exhaust systems or parts thereof include, but are not limited to, nonoriginal exhaust equipment

SAE standards typically involve measurements conducted in a controlled environment under stationary conditions.

Figure 4-1 presents a graphic of exhaust noise laws by state, taken from the SEMA (Specialty Equipment Marketing Association) Action Network website[2].

[2] https://www.semasan.com/

Figure 4-1: Exhaust Noise Law Type by State



4.5.3 Drive By Systems – SLM or Acoustic Camera

There are a few localities that use automated drive-by SLM-based testing systems for enforcing vehicle noise standards, similar to speed or red-light cameras. The City of New York uses a fixed system with multiple microphones to isolate sound levels from passing vehicles. This system is currently in use for issuing noise citations in the Borough of Manhattan.

Although it is a newly emerging technology, acoustic cameras have shown promise as a potential drive-by monitoring system. The acoustic camera is typically combined with a license-plate reading camera. Upon registration of an excessive sound level by the acoustic camera, the vehicle license plate is logged and appropriate action is taken. **Figure 4-2** shows an example of an acoustic camera and the overlay showing the source of the noise - the exhaust of the white van.

There are many examples of acoustic camera systems in use globally with a few in the U.S. New York City uses a fixed acoustic camera system at the northwest corner of the intersection of East 96th Street and 5th Avenue. Newport, Rhode Island, uses a trailer-mounted portable acoustic camera system to enforce vehicle noise limits. **Figure 4-3** shows a picture of the Newport system deployed at an intersection.

Figure 4-2: Example of a Fixed Acoustic Camera System

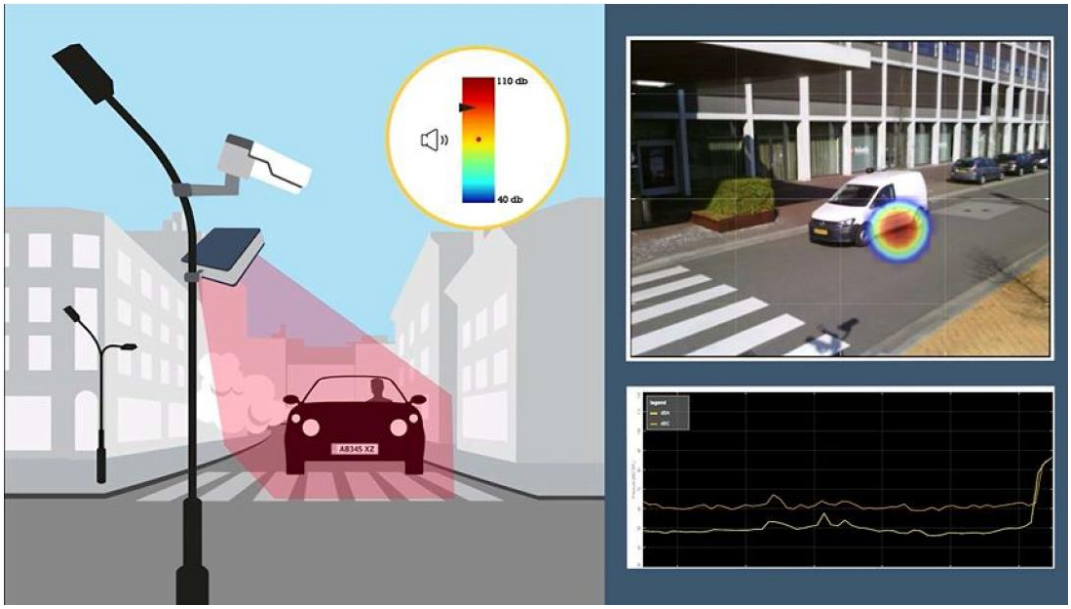


Figure 4-3: Trailer-mounted Acoustic Camera System in Newport, RI

5.0 Findings and Discussion

5.1 Discussion

This report was developed through a close review of source material (reports by VTrans staff and Parsons), stakeholder feedback, and a literature review of standards and methodologies related to assessing excessive vehicle noise.

This report does not recommend any specific approach for addressing excessive vehicle noise. The benefits and drawbacks of the various approaches and methodologies, coupled with associated costs, are intended here to assist the Legislature with understanding noise issues. This report is not an exhaustive analysis of noise, community response to noise, or determination of an optimal solution for addressing excessive vehicle noise.

5.2 Findings

A change to the VPIM that would require inspection mechanics to reject modified or excessively noisy exhausts for passenger vehicles / light trucks would be the simplest and least costly to implement vehicle noise control measure. This option would likely also be the least effective, as it is subjective and vehicle owners can remove aftermarket mufflers before inspections and then reinstall them after passing inspection.

Noise testing as part of the VPIM would provide an objective standard for vehicle noise levels and could be incorporated into the existing Automated Vehicle Inspection Program (AVIP) software. This is the most expensive option evaluated due to the number of sound level meters that would have to be purchased, calibrated, and maintained.

Noise testing could also be instituted in statute with enforcement performed by law enforcement personnel. This would require less equipment than implementing testing in the VPIM but would add additional training and enforcement responsibilities to law enforcement, potentially to the detriment of other safety enforcement activities that stakeholders considered to be higher priority.

A hybrid approach, similar to the system currently used in Maine, could also be implemented. This would allow law-enforcement to issue citations based on a subjective assessment of excessive vehicle noise. As an affirmative defense, the vehicle owner could have the vehicle tested at a selected set of state inspection stations with noise testing capability. If the vehicle sound levels were determined to be in compliance with the limit, the citation would be dismissed. This system would provide law enforcement with a mechanism to address excessive vehicle noise without requiring all officers or inspection mechanics to learn noise testing.

Using acoustic camera-based automated testing systems could provide a scalable, objective vehicle noise testing solution that would not add any additional burden to law enforcement or inspection stations. This option would require modifications to existing Vermont Statutes to allow unattended / remote enforcement. These changes are being investigated by other parties as part of research into the practicality of speed cameras. Costs in this report for this option are based on ten stations, but a pilot program could be implemented to investigate the feasibility of the system by using fewer stations. This

would likely be the most effective option, as the acoustic cameras measure sound levels from vehicles in motion and are capable of isolating sound from the vehicle under investigation.

Appendix A. Local Vermont Noise Ordinances

Burlington, VT Code of Ordinances

Ch. 20 Motor Vehicles and Traffic Article I. In General
20-9 Mufflers:
(a) Every motor vehicle shall, at all times, be equipped with a muffler in good working order and in constant operation to prevent excessive and unusual noise and annoying smoke.
(b) It shall be unlawful for any person to drive or operate any motor vehicle in the city with a cutout, an exhaust whistle without a muffler or with an exhaust system which has been altered, tampered with or changed from its original construction, thereby causing such motor vehicle to make a louder noise than it would have in its original condition.

https://www.codepublishing.com/VT/Burlington/#!/Burlington20/Burlington2001.html#20-9

Bennington, VT Ordinances

Article 24 Noise Control
24-4 Mufflers:
A motor vehicle, including a motorcycle, moped, snowmobile, all-terrain vehicle, or other vehicles must be equipped with a muffler in good working order and in constant operation to prevent excessive or unusual noise and annoying smoke. A person shall not remove, destroy, or damage any of the baffles contained in the muffler, nor shall a person use a muffler cutout, bypass, or similar device upon any such vehicle. Such vehicle shall at all times be equipped with a properly operating exhaust system which shall include a tail pipe and a resonator on a vehicle where the original design included a tail pipe and resonator.

https://cms5.revize.com/revize/bennington/Document%20Center/Government/Ordinances/Ordinance-24-Noise-Control.pdf

Woodstock, VT Adopted Noise Ordinances

Chapter 3. Noise Control
§5305. Mufflers:
A motor vehicle, including a motorcycle, moped, snowmobile, all-terrain vehicle, or other vehicles must be equipped with a muffler in good working order and in constant operation to prevent excessive or unusual noise and annoying smoke. A person shall not remove, destroy, or damage any of the baffles contained in the muffler, nor shall a person use a muffler cutout, bypass, or similar device upon any such vehicle. Such vehicle shall at all times be equipped with a properly operating exhaust system which shall include a tail pipe and a resonator on a vehicle where the original design included a tail pipe and resonator.

https://townofwoodstock.org/government/village-ordinances/adopted-noise-ordinance/

Alburgh, VT Noise Control Ordinance

Town of Alburgh Noise Control Ordinance
4) Exhausts:
The discharge into the open air of the exhaust of any steam or internal combustion engine, or any motorized vehicle, except through a muffler or other device, which effectively prevents loud or explosive noises there from.

https://alburghvt.org/wp-content/uploads/2021/01/TOWN-OF-ALBURGH-NOISE-ORDINANC E-23.pdf

Williston, VT Noise Control Ordinance

Town of Williston Noise Control Ordinance
4.8 Exhausts:
The discharge into the open air of the exhaust of any steam or internal combustion engine, or any motorized vehicle, except through a muffler or other device, which effectively prevents loud or explosive noises there from.

https://willistonvt.govoffice3.com/vertical/Sites/%7BF506B13C-605B-4878-8062-87E5927E49F0%7D/uploads/Noise_Control_Ordinance_(Amended_April_2020).pdf

Enosburg Falls, VT Noise Ordinance

Village Of Enosburg Falls An Ordinance In Relation To Objectionable Noise
Section 1003, 3. Mufflers:
Any vehicle or device equipped with and propelled by a combustion type engine, whether operated on a public street or on private property, must have a muffler. The owner of the vehicle or device shall maintain the muffler in constant operation to prevent excessive or unusual noise and annoying smoke. A person shall not remove, destroy, or damage the baffles contained in the muffler, not use a muffler cutout, bypass, or similar device upon any vehicle or device. All Vehicles or devices must have a properly operating exhaust system. A complete exhaust system shall include a tail pipe and a resonator on a vehicle where the original design included a tail pipe and a resonator.

https://villageofenosburgfalls.org/wp-content/uploads/2017/04/Noise-Ordinance.pdf

West Windsor, VT Noise Control Ordinance

Town of West Windsor Noise Control Ordinance
General Prohibitions,
2) Vehicular Operation:
Noise emanating from the operation of an automobile, motorcycle or other type of motor vehicle, in such a manner as to create abnormal engine, exhaust or tire noise.

https://westwindsorvt.govoffice2.com/vertical/sites/%7BD8CDCAEE-6783-4071-AE03-8A27DD92A280%7D/uploads/Noise_Ordinance_-_final(1).pdf

Putney, VT Ordinance Regulating Noise

Putney Ordinance Regulating Noise
Article III General Noise Standards, A. Exhaust:
This discharge into the open air of the exhaust of any internal combustion engine, whether operated on a public way or on private property, except through a muffler or other device which will effectively prevent loud or explosive noises therefrom.

https://cms3.revize.com/revize/putney/Documents/Government/Ordinances%20And%20Regulations/Noise_Ordinance.pdf

Rutland, VT Ordinance Amendments

Rutland City Board Ordinance Amendments
(c) (3):
Modify or cause to be modified the muffler, exhaust system or other noise-control device of any vehicle (physically, technically or otherwise) in a manner that will increase the noise emitted by such vehicle above that emitted by the vehicle when newly manufactured, regardless of the date of manufacture. The noise-control devices of any vehicle operated in the City of Rutland shall be maintained and in good working order. No person shall operate or permit to be operated a vehicle where the muffler, exhaust system or other noise- control device has been so modified or has not been maintained.

https://ecode360.com/41459649

Springfield, VT Code of Ordinances

Sec, 12-124- Certain noises prohibited
(3) General prohibitions, 4. Exhausts:

The discharge into the open air of the exhaust of any steam engine, internal combustion engine, motor boat or motor vehicle, except through a muffler or other device which will effectively prevent loud or explosive noises therefrom;

https://library.municode.com/vt/springfield/codes/code_of_ordinances?nodeId=PTIICOOR_CH12HESANU_ARTIINU_DIV5NUAFPESA_S12-124CENOPR

St. Albans, VT Vehicular Noise Ordinance

(d) Restricted uses and activities
2. Mufflers:
a. Every motor vehicle shall, at all times, be equipped with a muffler in good working order and in constant operation to prevent excessive and unusual noise and annoying smoke.
b. It shall be unlawful for any person to drive or operate a motor vehicle in the City with a cutout, an exhaust whistle, or without a muffler thereby causing such motor vehicle to make a noise that is plainly audible at a distance of 50 feet from such vehicle.

https://www.stalbansvt.com/vertical/sites/%7B6057F00C-4FBC-4942-B5A5-C142459B1038%7D/uploads/Vehicular_Noise_Ordinance_-_for_sharing.pdf

Appendix B. Visual Inspection and Noise Testing Options Cost Detail

Appendix B: Visual Inspection and Noise Testing Option Cost Detail

Option	Required Step Description	Estimated Cost (USD)	Frequency	Cost Estimate Details	Challenges	Benefits	Expected Efficacy
1) Visual Inspection - Change VPIM to require inspection mechanics to reject modified or excessively noisy exhausts for passenger vehicles / light trucks	Update rules through APA	2,200	One time	VTrans staff estimate	Affects all vehicles - not just noisy ones; Adds a step to the inspection process; May lead to failure for aftermarket exhausts which do not increase noise levels; May limit Vermont consumers ability to use aftermarket or non-OEM parts; Requires inspection mechanics to make a judgement call on excessive noise and/or aftermarket status of equipment; Low efficacy - vehicle owners can remove aftermarket mufflers before inspections and then reinstall them after passing inspection; Subjective - does not have an objective / quantitative limit. Will not detect vehicle noise due to motion such as engine braking noise, loud stereos, etc.	Ease of implementation; Low cost and no recurring cost; Uses existing inspection system.	Low
	Update and reissue VPIM	5,000	One time	Preliminary estimate (pending stakeholder feedback)			
	Changes to AVIP/Tablet software	21,000	One time	30% of Parsons estimate of the noise testing changes. There will be significantly fewer changes needed for visual inspection updates.			
	Marketing / education campaign to train inspection mechanics on changes (mailer, email, website updates)	3,200	One time	$2 / shop for a mailer explaining the changes, $1k for website updates and emails			
	TOTAL One-Time Cost	**31,400**	**One time**				
	TOTAL Annual Recurring Cost	**-**	**Annual**				
2) Noise Testing - as part of the VPIM - vehicle inspection mechanics as enforcement	Update rules through APA	2,200	One time	VTrans staff estimate	Affects all vehicles - not just noisy ones; Difficult to determine the appropriate sound level limit; Difficult to test noise in a shop environment; Inspection stations may need to find alternative test locations; Inspection stations may not be willing to incure additional equipment costs; Additional equipment required; Additional time and cost for Vermont residents during inspections; Low efficacy - vehicle owners can remove aftermarket mufflers before inspections and then reinstall them after passing inspection; Recurring annual costs due to meter maintenance and calibration; Will not detect vehicle noise due to motion such as engine braking noise, loud stereos, etc.	Implements an objective standard; All vehicles tested; No additional burden on law enforcement.	Low / Moderate
	Changes to AVIP/Tablet software	70,000	One time	Parsons estimate			
	Update and reissue VPIM	5,000	One time	Preliminary estimate (pending stakeholder feedback)			
	Purchase sound level meters for inspection stations	550,000	One time	Approximately 1,100 inspection shops in Vermont. $500 per shop hardware cost for sound level meter / calibrator.			
	Marketing / education campaign to train inpsection mechanics on changes (mailer, email, website updates, online training video)	17,000	One time	$10 / shop for a mailer / manual explaining the changes and providing training, $5k for the production of an online training video for inspection stations, $1k for website updates and emails			
	2-year calibration for inspection station sound level meters	55,000	Annual	$100 / calibration. 550 meters calibrated per year for a 2 year calibration interval for 1,100 meters			
	Replacement and meter maintenance	55,000	Annual	10% annual replacement of sound level meters due to wear and tear assuming a 10 year service life, also covers maintenance and repair costs			
	TOTAL One-Time Cost	**644,200**	**One time**				
	TOTAL Annual Recurring Cost	**110,000**	**Annual**				
3) Noise Testing - in Statute - Law enforcement as enforcement	Update Legislation	2,200	One time	Vtrans staff estimate	Difficult / impossible to test noise on the side of road; Difficult to determine the appropriate sound level limit; Law enforcement must make a subjective determination of which cars to test; Only subjectively noisy vehicles tested so some noisy vehicles may be missed; Additional demand on limited law enforcement resources - diverts traffic stop attention away from speed / DUI / other safety enforcement; Law enforcement may not use or implement noise testing equipment due to other obligations.	Implements an objective standard; Testing occurs on vehicles as they are driven, not during a scheduled test - this eliminates owners removing aftermarket mufflers before inspections; Testing can be performed while vehicle is in motion to detect vehicle noise such as engine braking noise, loud stereos, etc.	Moderate
	Develop one-hour training course for officers	15,000	One time	Preliminary estimate (pending stakeholder feedback)			
	Purchase sound level meters for law enforcement	250,000	One time	200 sound level meters for troopers, 300 for local and county - $500 per meter			
	Train officers on sound level meter use	25,000	Annual	Training / certification for officers on a rolling basis, with 250 officers trained per year. This would allow for recertification every 5 years. Assumes $100 / course admin cost and lost labor cost.			
	2-year calibration for sound level meters	25,000	Annual	$100 / calibration. 250 meters calibrated per year for a 2 year calibration interval for 500 meters			
	Replacement and meter maintenance	25,000	Annual	10% annual replacement of sound level meters due to wear and tear assuming a 10 year service life, also covers maintenance and repair costs			
	TOTAL One-Time Cost	**267,200**	One time				
	TOTAL Annual Recurring Cost	**75,000**	Annual				
4) Noise Testing - in Statute - Testing after citation (25 testing stations are included in the cost estimate)	Update Legislation	2,200	One time	Vtrans staff estimate	Requires a subjective judgement by law enforcement to issue citation Only subjectively noisy vehicles tested so some noisy vehicles may be missed, Additional demand on limited law enforcement resources - diverts traffic stop attention away from speed / DUI / other safety enforcement, Difficult to determine the appropriate sound level limit, Difficult to test noise in a shop environment, Inspection stations may need to find alternative test locations, Inspection stations may not be willing to incur additional equipment costs, Additional equipment required, Additional time and cost for cited individuals, based on a subjective judgement by law enforcement, Low efficacy - vehicle owners can remove aftermarket mufflers before the defense inspection and then reinstall them after passing inspection, Smaller number of testing stations so may be inconvenient for cite individuals to find a testing station, Recurring annual costs due to meter maintenance and calibration, Will not detect vehicle noise due to motion such as engine braking noise, loud stereos, etc.	Only effects vehicles which are subjectively noisy, Gives law enforcement a method to control excessive vehicle noise that doesn't require additional equipment Gives cited individuals an objective defense Significantly lower startup cost than other noise testing options With limited testing stations, fewer sound level meters need to be purchased and lower annual recurring costs	Moderate
	Develop 30-minute training course for officers	10,000	One time	Preliminary estimate (pending stakeholder feedback)			
	Update rules through APA	2,200	One time	VTrans staff estimate			
	Purchase sound level meters for 30 testing stations	15,000	One time	30 sound level meters for inspection stations - $500 per meter			
	Marketing / education campaign to train inspection mechanics on changes (mailer, email, website updates, online training video)	7,500	One time	$50 / shop for a mailer explaining the changes plus manual and basic training, $5k for the production of an online training video for inspection mechanics, $1k for website updates and emails			
	Train officers on new rules	62,500	One time	Train all officers once on the new rules / citation. Assumes $100 / hour for training, 30 minutes of training per officer			
	Update and reissue VPIM	5,000	One time	VTrans staff estimate			
	Changes to AVIP/Tablet software	70,000	One time	Parsons estimate			
	2-year calibration for sound level meters	1,250	Annual	$100 / calibration. 12 - 13 meters calibrated per year for a 2 year calibration interval for 25 meters			
	Replacement and meter maintenance	1,500	Annual	10% annual replacement of sound level meters due to wear and tear assuming a 10 year service life, also covers maintenance and repair costs			
	TOTAL One-Time Cost	**174,400**					
	TOTAL Annual Recurring Cost	**2,750**					
5) Noise Testing - in Statute - Automated Drive-by-Monitoring by sound level meter or acoustic camera (10 monitoring locations are included in the cost estimate)	Update Legislation to allow remote enforcement via civil action	20,000	One time	Placeholder estimate. This should be updated based on the findings of other pending legistlative research reports.	Will require changes to Vermont statutes to allow unattended / remote enforcement; High cost per station; Requires software development and system integration; Legal challenges to accuracy and repeatability - similar to speed cameras; SLMs will not isolate individual vehicles except in specially configured locations.	Implements an objective standard; No additional burden on law enforcement; Measures vehicles in motion as they are driven so will enforce consistent limits for all vehicle noises - exhausts, brakes, stereos, and tire squeal; Acoustic cameras can isolate sound from specific vehicles.	High - for acoustic cameras, Moderate - for sound level meters
	Purchase fixed-position or mobile drive-by noise monitoring stations	250,000	One time	Manufacturer estimate of 25k per station cost, assume 10 stations			
	Installation costs	100,000	One time	10k per site to cover power, internet, pole, concrete work, etc.			
	Software development for automated civil action generation	80,000	One time	Preliminary estimate (pending stakeholder feedback)			
	Annual power, internet service, maintenance	3,000	Annual	Preliminary estimate (pending stakeholder feedback)			
	Software maintenance contract	8,000	Annual	Estimate at 10% of development cost. (Preliminary, pending stakeholder feedback)			
	Replacement and meter maintenance	25,000	Annual	10% annual replacement of sound level meters due to wear and tear assuming a 10 year service life, also covers maintenance and repair costs			
	TOTAL One-Time Cost	**450,000**					
	TOTAL Annual Recurring Cost	**36,000**					

VERMONT
AGENCY OF TRANSPORTATION

PARSONS

EXCESSIVE VEHICLE NOISE REDUCTION REPORT

Vermont Automated Vehicle Inspection Program (AVIP)

AUGUST 2024

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Context

As part of a legislative inquiry response, the Vermont Department of Motor Vehicles (DMV) requested Parsons to investigate and assess ways to measure excessive vehicle noise. The directives included:

- Investigate available technology to measure vehicle noise.
- Assess the feasibility of using the technology in the AVIP.
- Outline integration with the AVIP Tablet and process.
- Investigate options to address vehicle noise that does not involve noise testing.

On behalf of the State of Vermont, Parsons researched available technologies to measure vehicle noise and theorized how to include vehicle noise inspections in the AVIP.

Investigating Available Technology to Measure Vehicle Noise

Parsons researched three possible technologies which the State of Vermont could incorporate into the AVIP to measure vehicle noise.

- Sound Pressure Level Meters
- Audio/Noise Level Meter (Dosimeters)
- Drive By Noise Monitoring Systems

Sound Pressure Level Meter

A Sound Pressure Level (SPL) Meter is a handheld instrument with a microphone used to determine acoustics levels. The movement of the diaphragm inside the microphone responds to changes in air pressure caused by sound waves. This electrical signal is then converted into sound pressure units - decibels (dB).

The device utilizes a microphone to sample noise at a predetermined rate. A preamplifier adjusts the signal strength, which undergoes processing by the Digital Signal Processor (DSP), starting with frequency weighting. After frequency weighting, the signal either undergoes time weighting or directly moves to linear integration. Integration means the sound level meters calculate average readings over a specific period.

SPL measures sound levels in a standardized way. It responds to sound in approximately the same way as the human ear and gives objective, reproducible measurements of sound pressure levels, making it viable for usage in an inspection station. The operational setup includes configuring these features and selecting the appropriate functions for the specific measurement task. The device operates on either internal batteries or an external power source.

The SPL Meter could be used to measure the vehicle noise during an inspection.

There are two Classes of SPL Meters are available, each with different tolerances.

Performance criteria: tolerance limits at reference frequencies (for IEC61672-1:2013)	Class 1	Class 2
Frequency of 16Hz	+2.5 dB, -4.5 dB	+5.5dB, – ∞dB
Frequency of 20Hz	+/- 2.5 dB	+/- 3.5 dB
Frequency of 1kHz	+/- 1.1 dB	+/- 1.4 dB
Frequency of 10kHz	+2.6 dB, -3.6 dB	+5.6 dB, -∞ dB
Frequency of 16kHz	+3.5 dB, -17 dB	+6.0 dB, -∞ dB

The Class 1 SPL is more accurate as displayed but comes with a higher purchase cost. Reference the chart above for some sample differences between Class 1 and Class 2 meters. Please note, the differences between Classes differ between brand, model, and release of the device.

Several SPL meters were used to compare and test with; connectivity, data receiving and data storing were successful. Tests were performed around data recording and how this method may be used within the AVIP.

- ✓ SPL meters can be used in inspection stations.
- ✓ Certain SPL meters may be integrated into an automated computerized system
- ✓ Certain SPL meters are configured to log data wirelessly
- ✓ SPL meters require no infrastructure development
- ✓ SPL meters are accurate up to 0.1 dB
  - SPL meters have variability from 1 dB to 3 dB depending on the Class
- ✓ The SPL meter must be calibrated
  - The SPL meter requires a separate calibration device
  - The SPL meters calibration device costs $250 - $1,500 or more.
- ✓ SPL meters may be field calibrated
- ✓ The SPL meters have variable costs depending on the class
  - Class 1 SPL meter costs range from $2,500 - $8,000 or more
  - Class 2 SPL meter costs range from $150 - $750 or more

Audio/Noise Level Meter (Dosimeter)

The Audio/Noise Level Meter is a category of instruments designed to measure unwanted sounds and compare them to established limits. These meters often take the form of either noise dosimeters or noise monitoring stations. Noise dosimeters are wearable devices that measure an individual's noise exposure over a set period, commonly used in occupational health assessments to ensure safe noise levels. Noise monitoring stations are fixed installations designed for long-term, continuous measurement and logging of ambient noise. These stations are frequently used for quality control in the manufacturing and servicing of audio products like speakers, mobile phones, and earphones.

Essentially, the Audio/Noise Level Meter uses a microphone to determine how well a person can hear certain sounds rather than how loud the sound actually is. These systems employ Fast Fourier Transform (FFT) analyses, allowing it to measure how sound impacts the human ear over time, not in the moment. Audio level meters require frequent calibration to measure the vehicle noise. Although this technology may not be the most effective option to measure individual vehicle noise, it is worth exploring.

Parsons configured a digital noise meter that utilized FFTs as the analysis to see the difference between Dosimeters and SPL meters.

- ✓ Dosimeters can be used in inspection stations.
- ✓ Certain dosimeter may be integrated into an automated computerized system
- ✓ Certain dosimeters are configured to log data wirelessly
- ✓ Dosimeters require no infrastructure development
- ✓ Dosimeters are accurate up to 0.1 dB
  - Dosimeters have variability from 1 dB to 3 dB depending on the Class
- ✓ Dosimeters must be calibrated
  - Dosimeters requires a separate, in field, calibration device
  - Dosimeters calibration device costs $1,500 or more
- ✓ Dosimeters have variable costs depending on the class
  - Class 1 Dosimeters costs range from $5,000 - $10,000 or more
  - Class 2 Dosimeters costs range from $500 - $3,000 or more

Drive-by Noise Monitoring Systems

Drive-by Noise Monitoring systems are an immobile solution for monitoring vehicle noise levels. We researched two different types of Drive-by Noise Monitoring systems: Roadside and Station-Based.

Roadside systems require a fixed location, such as an intersection, or along a major or minor street. Dedicated infrastructure is required, including power and cellular or fixed wi-fi connection. Roadside systems can be run indefinitely or in the short term. Fixed Noise Cameras measure ambient sound and the sound of passing vehicles. This approach picks up other environmental noise, such as other vehicles on the road, at the same time as the vehicle being targeted by the system. Isolating test results would be difficult to ensure a specific vehicle is creating the noise on public roadways, because the Drive-by Noise Monitoring system would identify where the noise originates *but not specifically which vehicle is causing the noise*. Note that these systems, left unattended, can be damaged or stolen. Drive-By Noise Monitoring Systems have the ability to send real-time notifications of noise-violating vehicles to law enforcement.

An alternative Drive-by Noise Monitoring System requires a dedicated large, indoor facility. These Station-Based systems are generally designed for vehicle certification and involve specialized test tracks measure noise, vibration, and harshness (NVH). Testing also involves chassis dynamometer test cells and high-performance test equipment to produce comparable measurement results. Vehicles would pass through the facility one at a time to determine vehicle noise.

Due to the nature of these devices, Parsons engaged companies offering product solutions but did not conduct a hands-on analysis. We found that:

- ✓ Only one type of Drive-by Noise Monitoring Systems can be used in inspection stations, with a large, dedicated facility required
- ✓ Roadside Drive-by Noise Monitoring Systems can be used in the field
  - Roadside Drive-by Noise Monitoring Systems require an Automated License Plate Reader (ALPR) or some type of vehicle identification system to correlate vehicle data.
- ✓ Certain Drive-by Noise Monitoring Systems may be integrated into an automated computerized system
- ✓ Certain Drive-by Noise Monitoring Systems are configured to log data wirelessly
- ✓ Either type of Drive-by Noise Monitoring Systems requires infrastructure development
- ✓ Drive-by Noise Monitoring Systems are accurate up to 0.1 dB
  - Noise variability depends on the specific Drive-by Noise Monitoring System
- Drive-by Noise Monitoring Systems must be calibrated
  - Drive-by Noise Monitoring Systems requires a separate, in field, calibration device
  - Drive-by Noise Monitoring Systems calibration device costs $1,500 or more.
- Drive-by Noise Monitoring Systems costs range from $15,000 – $345,000

Overview of Findings

Technology	Benefits	Drawbacks/Concerns
Sound Pressure Level Meter	• Cost Effective Class 2 device • Mobile, hand-held device • Can be integrated with AVIP • Accurate measuring device • Bluetooth Capable • Standardized use in automotive industry • Easy to use	• Requires frequent calibration • Two classifications – Class 1 costly • Best suited in controlled environment
Audio/Noise Level Meter (Dosimeter)	• Determines noise exposure • Bluetooth Capable • Easy to use	• Measures noise over time • Requires frequent calibration • Requires controlled environment • Generally designed to be worn on the body
Drive-by Noise Monitoring Systems	• Passive data collection • Real-time monitoring on road • Targeted intervention (used in areas receiving frequent complaints)	• Expensive • Immobile with dedicated infrastructure required • Picks up other environmental noise • Environmental interference (rain, construction, etc.) • Can be stolen or damaged • Regulatory compliance may be required • Requires an ALPR system to identify vehicles • Limited to vehicles that cross path with system

Assess Feasibility of Technology Use in AVIP

Parsons has assessed the following technologies for use in AVIP:

- ✓ SPL Meters
- ✓ Noise Dosimeters
- ✓ Drive-by Noise Monitoring Systems

Each technology is technically feasible and may be used within the AVIP to enhance reporting on vehicles that exceed allowed noise emissions. SPL meters and Noise Dosimeters require no additional infrastructure to employ. Drive-by Noise Monitoring systems require extensive planning, investment, and setup.

Considering the three technologies, employing a SPL Meter or a Dosimeter into the AVIP would require the least amount of additional hardware. Over two thirds of the required equipment is already established at the inspection stations as part of the AVIP, which employs the use of a wireless router acting as an access point as well as a wireless, ruggedized Tablet equipped with both Wi-Fi and Bluetooth. Parsons tested meters that had real-time communications capability though Bluetooth, others currently offered as commercial off the shelf use similar technology. The device would communicate the noise emissions data back to the Inspection Tablet, which would then communicate the data to the Vehicle Inspection Database (VID). The AVIP VID, with some software changes, could communicate, record, store, and analyze the noise emission data from an SPL Meter or Noise Dosimeter.

The Drive-by Noise Monitoring system would require more equipment as well as infrastructure development. The solution is still technically feasible, as noise data would be sent directly to the VID, with inspection mechanics retrieving the data during the AVIP emissions test. Outside of technical feasibility, this solution may not meet budget feasibility and it may not fit within resource constraints. Additionally, this solution entails a lot of complexity to appropriately implement, further reducing feasibility. With each setup, a separate but matching vehicle identification system may need to be implemented. This would match vehicles with the noise emissions as they drive by. This adds complexity and cost.

Implementing the Vehicle Noise Test, regardless of the technology, introduces several complexities:

Inspection Location and Environmental Noise

In a facility where more than one vehicle is being inspected, the SPL Meter and Dosimeter require additional effort and coordination for testing within multiple lane facilities. Noise emissions from one test could impact another test running in parallel. Stations that have multiple inspection lanes would need to ensure that tests performed are not impacted by other vehicle noise tests.

Errant noise pollution created from repairs done within an inspection station can impact the test. Common equipment such as pneumatic drivers, compressors, and shop vacuums may overtake the noise generated by a stock engine and exhaust system, causing the vehicle to fail.

This will require coordination between lanes to stagger the noise tests to ensure proper data gathering without impacting inspection throughput. Providing education to both inspection mechanics and Station Owners on what the Vehicle Noise Test involves, and the importance of staggering testing, would be necessary to successfully implement the Vehicle Noise Test.

Environmental noises, such as overhead air traffic and heavy truck traffic, could would impact the results of a noise test and would need to be managed.

One possible solution to combat errant station noise, concurrent vehicle testing, and/or a noisy environment from impacting a test would be to utilize a quiet period before the test begins. By using the Meter prior to beginning the emissions test, looking for noises that exceed an allowable level, an inspection mechanic would be able to detect an invalid test before beginning additional testing.

Inspection Mechanic Training

Implementing Vehicle Noise Testing into the AVIP would require supplemental training for the user, in this case, an Inspection Mechanic. How-to instructions, including video, would be beneficial to the user. Additionally, the development and implementation of on-demand instructional support directly on the Tablet would further enhance implementation. The training should include how to properly calibrate, set up, and operate the SPL meter in a station environment. Each step in the testing would also need to be explained and demonstrated.

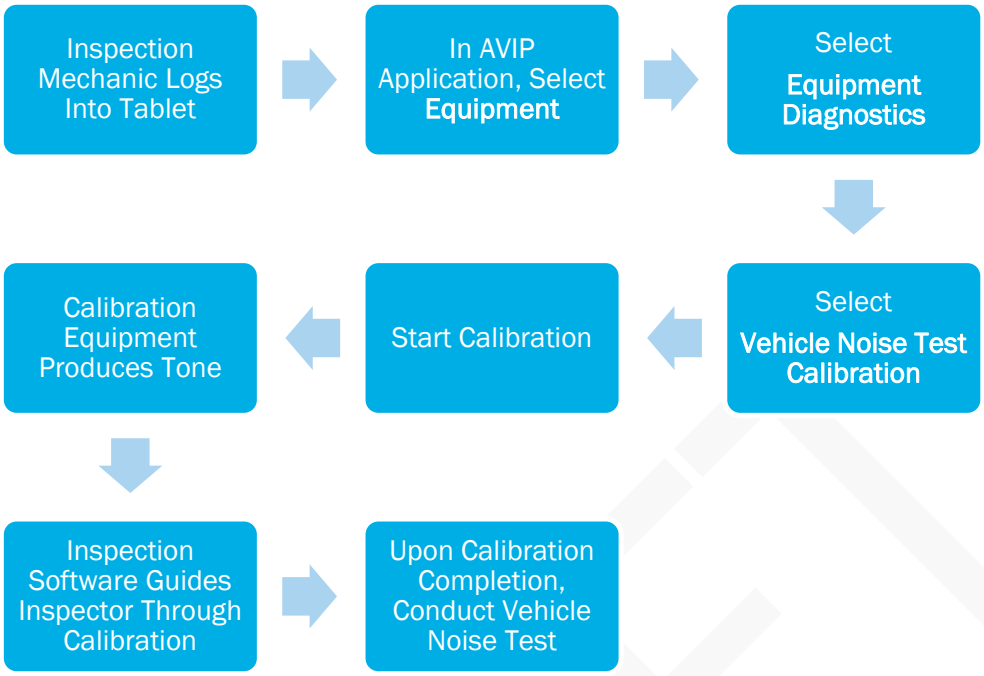
Inspection Process Updates

New software development would be required for the inspection application, as well as updated inspection procedures to include the Vehicle Noise Testing process.

The guided software would need to be modified to include instructions on how to properly perform a Vehicle Noise Test. Performing a test would start with the Inspection Mechanic following a series of screens breaking down each action into building blocks easy to comprehend and follow. Depending on the solution selected, the application could change the dialogs to the user. For example:

- If a SPL Meter or Dosimeter is used: Instructions would outline the placement of the Meter two feet away from the tailpipe and press the “Start Noise Test” button. The Inspection Tablet would then instruct the Inspection Mechanic to start the vehicle. Through the new software, data collection would run automatically. At the end of the data collection period, the Tablet would direct the Inspection Mechanic to the next step of the inspection process.
- If a Drive-by Noise monitoring system is used, the software would instruct the inspection mechanic to advise the customer where to take the vehicle for the test to be automatically performed.

In addition to procedural changes, each Vehicle Noise Testing solution requires frequent calibration to ensure quality and accuracy. To calibrate the noise meter, calibration equipment would produce an audible tone at a specified dB level, which the Inspection Mechanic would then validate on the inspection tablet as the meter registers the sound. The updated inspection software would lead the Inspection Mechanic through the necessary steps to adjust the meter’s calibration. This ensures the meter runs consistently within acceptable parameters.



The frequency of tests would be configurable, based on in-field testing. The default would be set to require equipment calibration at least once every five tests and at least once every two days. Once the equipment is calibrated, the calibration count would reset and allow five tests to be performed within two days. During the Vehicle Noise Test, the Inspection software would prompt the Inspection Mechanic to perform a calibration test prior to conducting the test, if required based on the default frequency points. The inspection software should not allow the Vehicle Noise Test to proceed until the meter is calibrated.

Pilot Testing

Introducing a pilot program would ensure full feasibility of the Vehicle Noise Test. Engaging the pilot stations already established in the AVIP would assist in the validation of the inspection process, as these stations are familiar with the process as it exists currently. During the pilot program, exploration of the equipment acquisition, inspection application software changes, and training development for the Inspection Mechanic and station owners would be required. The pilot program would also allow for risk mitigation by providing early data analysis through testing the real-world feasibility against inspection station environments.

Currently in the AVIP, pilot testing has been performed on software updates and changes using pilot stations. Pilot testing the Vehicle Noise Testing with the already established pilot stations will mitigate risk without impacting the entire program, ensuring a smooth implementation.

Pilot testing provides invaluable feedback. Through pilot programs, stations are empowered to provide unfiltered accurate and raw feedback. This data provides critical understanding to the challenges found in the field rather than within a test environment.

Outline the Integration with the AVIP Tablet and Process

SPL Meter and Dosimeter Noise Monitoring Integration

The SPL Meter and Dosimeter could both follow this outline to be integrated into the AVIP:

The AVIP currently uses two of the components required to run the Vehicle Noise Test in the AVIP:

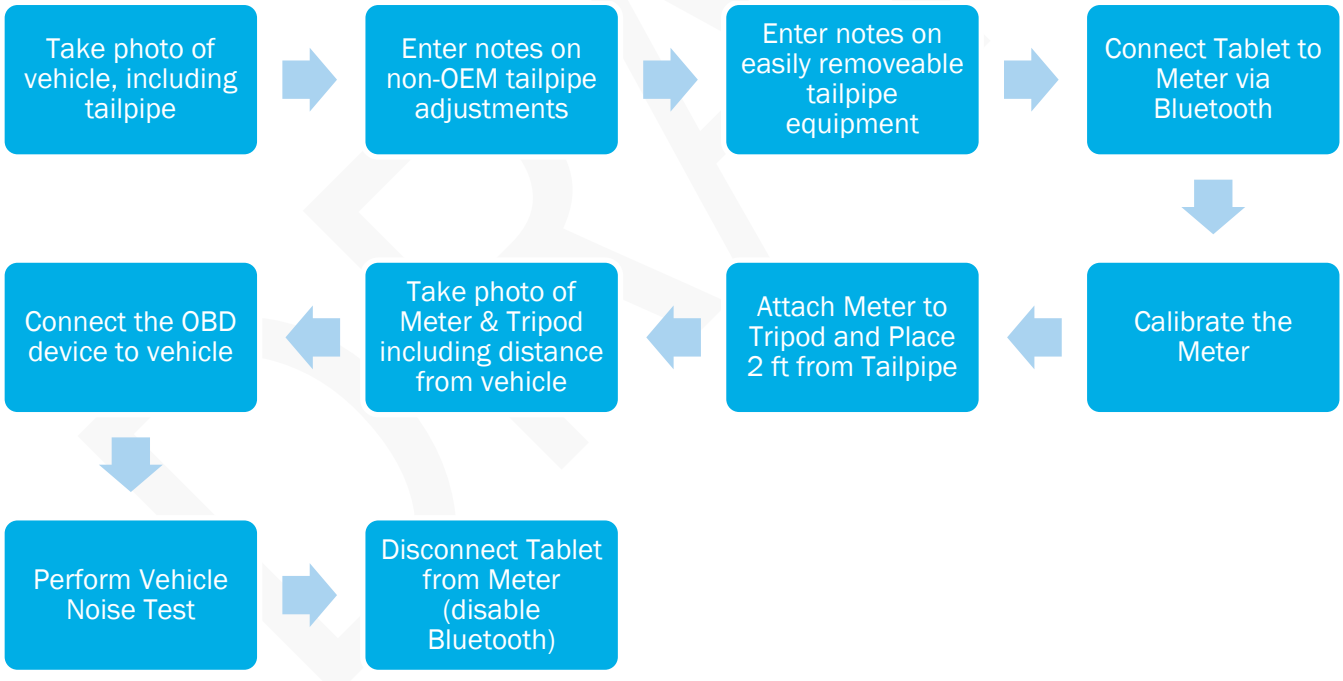
- Inspection Tablet – used to communicate with the Bluetooth-enabled SPL Meter.
- OBD Communication Device – used to conduct rest the vehicle inspection.

To incorporate a Vehicle Noise Test into the AVIP, the following equipment would be required in the inspection stations:

- Calibrated Class 2 SPL Meter or Dosimeter – to conduct the Vehicle Noise Test.
- Calibration Equipment – for calibration of the SPL Meter before each test.
- Tripod – for standardized placement of the SPL Meter two feet from the tailpipe.

New software development must include inspection process updates for the Vehicle Noise Test.

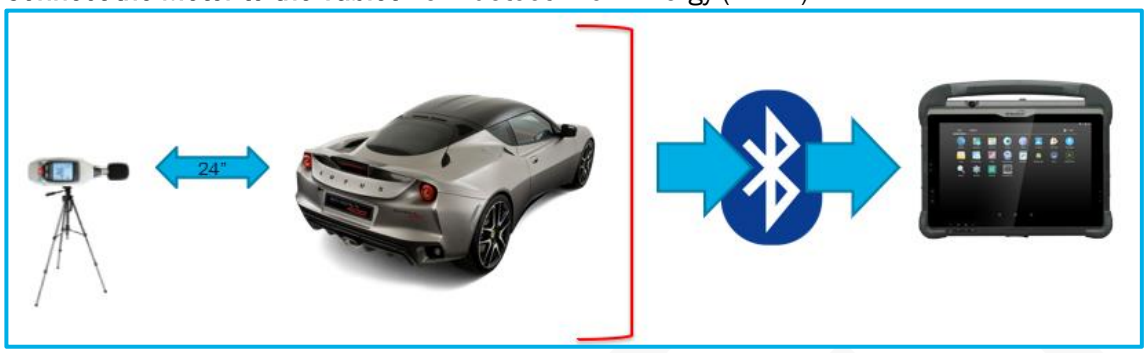
To perform the test using the SPL Meter, the new software/inspection process will guide the Inspection Mechanic through the procedures outlined below:



1. **Take a photo of the inspected vehicle, and particularly its tailpipe configuration and design**. Taking a photo of the tailpipe during the inspection allows Enforcement Officers to identify if the tailpipe on the vehicle has been modified since the inspection using the test record in the Parsons Enforcement app. Enforcement Officers could then either require reinspection or to issue a citation if the vehicle noise is too loud on an uninspected tailpipe.

2. **Direct the Inspection Mechanic to look for, and document, any tailpipe and muffler modifications**. This would include easily removable tailpipe caps, welded-in performance mufflers, and aftermarket modifications. Such equipment would suggest that the motorist may have modified the catalytic converter, replaced the stock muffler, and/or may have a cap on the exhaust system causing noise pollution. This would mean that the vehicle now requires a silencer.

3. **Connect the Meter to the Tablet** via Bluetooth Low Energy (BT-LE).



4. **Calibrate the Meter**. This process can vary from one meter to the next, however, the Inspection Mechanic will generally:
    a. Set the calibration tool to a specific output (94 dB or 114 dB);
    b. Press "Continue" on the Tablet to initiate the calibration process for the meter, allowing it to identify the output of the calibration tool; and
    c. Adjust the Meter's offset either positive or negative to match the calibration tool based on the calibration findings.

5. **Attach Meter to Tripod** (if needed) and place the tripod 2 ft away from the tailpipe.

6. **Take a photo of the Meter and Tripod**, including the distance from the inspected vehicle, using the AVIP application (for test validation).

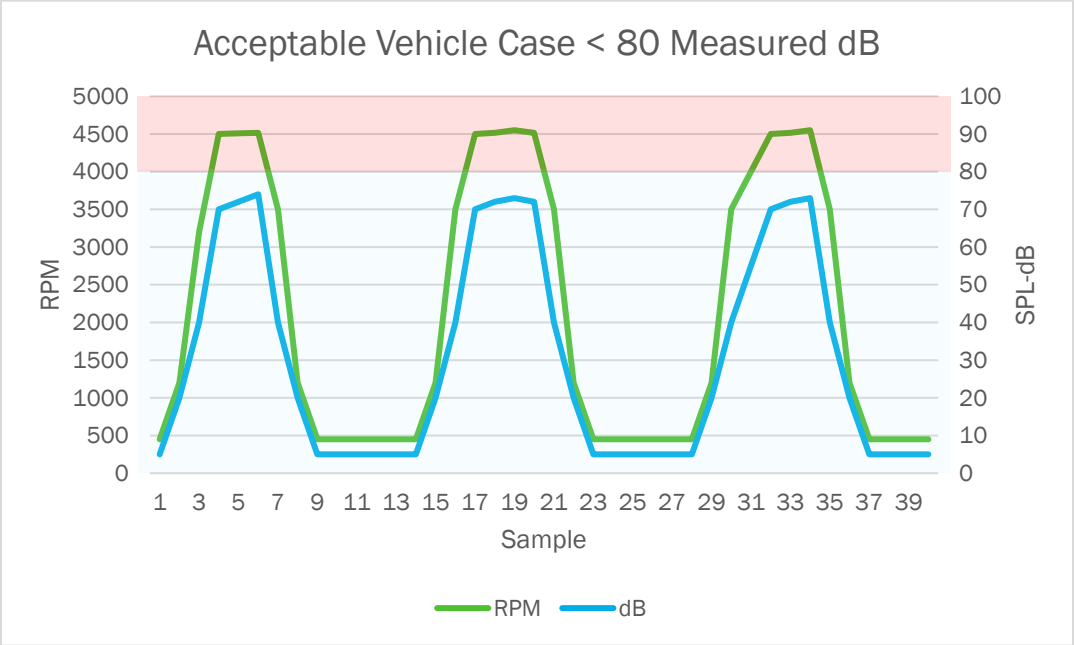
7. **Connect the OBD device to the vehicle**.

8. **Perform the Vehicle Noise Test**, including an engine snap-like operation of the vehicle while in neutral, which involves depressing the acceleration (gas) pedal to have the motor RPM increase and then releasing to come back to idle. This would be done at least three times to get accurate noise measurements from the Meter. The inspection software would walk the Inspection Mechanic through the process step-by-step.

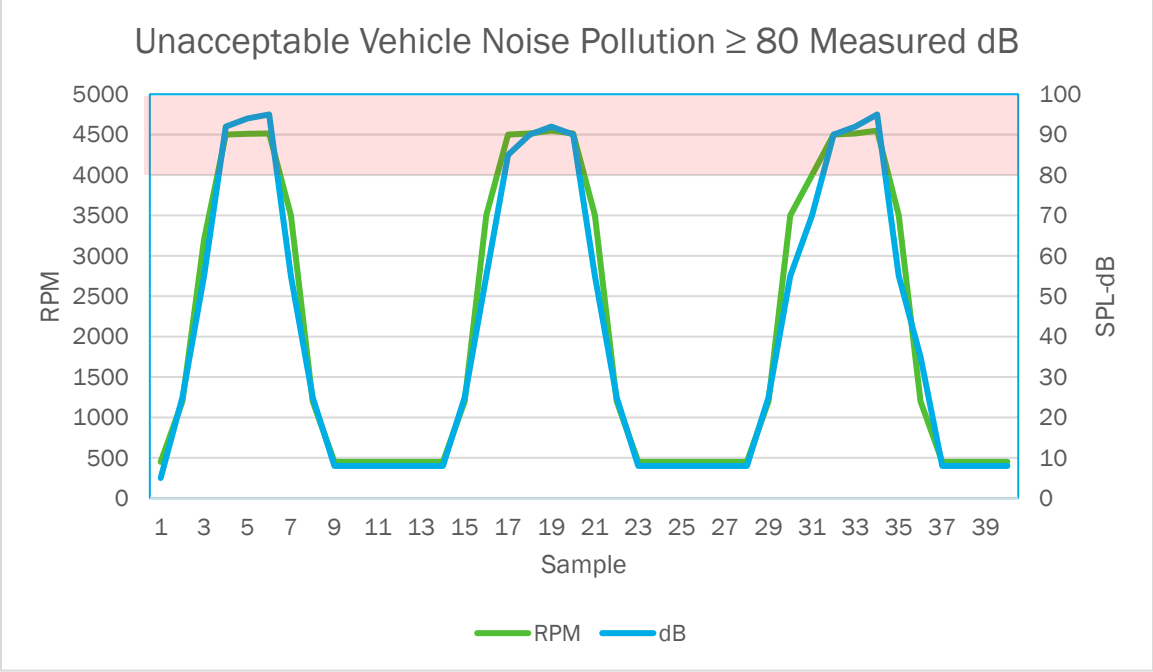
9. **Disconnect Tablet** from the Meter.

As the test is being performed, the tablet gathers the Vehicle Noise data. There are three data points the tablet collects, one of which is used for test integrity. The first is vehicle Rotations per Minute (RPM). The second is Vehicle Noise output (in decibels [dB]). The data between the RPM and the dB output should directly correlate as the engine is stressed. The third data point is the throttle value, and that is used to ensure that the driver is pressing on the throttle/pedal to validate that the vehicle is being tested.

The test results would be based on legislated or acceptable values. Once the allowable noise pollution level was determined, the application would display where the collected data falls. The charts below show two lines, the blue line is the noise pollution (dB) and the green line is the RPM. When the dB value exceeds the threshold (shown as 80 dB on the following page), the vehicle would fail the test..



AN ACCEPTABLE VEHICLE CASE IN WHICH THE SOUND LEVELS DURING TESTING REMAIN LESS THAN 80 DB



AN UNACCEPTABLE VEHICLE NOISE POLITION TEST, AS SEEN BY THE DECIBLE COUNT HOVERING IN THE RED ZONE, ABOVE 80 DB.

Data gathered throughout the Vehicle Noise Test would be securely sent to the Vehicle Inspection Database (VID) for analysis. The data points would include the photos, tailpipe modifications, results of the test, and a message on the Vehicle Inspection Report (VIR).

Drive-by Noise Monitoring Integration

To integrate the Roadside Drive-By Noise Monitoring System into the AVIP, a location would be chosen.to conduct data collection. This location would require full infrastructure, including power and a cellular and/or Wi-Fi network for data transfer to the AVIP Vehicle Inspection Database (VID). Additionally, an Automated License Plate Reader (ALPR) system would need to be installed. The ALPR system is used to record the vehicle being analyzed.

Vehicles passing by would be scanned using the Roadside Drive-By Noise Monitoring System and correlated to the results of the ALPR data. This information would be sent back to the VID in real-time for immediate processing. Upon the vehicle's annual inspection in the AVIP, their most recent Noise Monitoring results, and/or the data collected over the year, will be presented to the Inspection Mechanic for tailpipe analysis. Regulation would be necessary to act upon a failing vehicle outside of the inspection facilities.

Data collected during times of high traffic noise, weather irregularities, construction activities, or other noise-creating events may invalidate the results. Data collected on vehicles not correlated with information collected by the ALPR system would also be invalidated.

To integrate the Station-Based Drive-by Noise Monitoring System with AVIP, limiting the opportunity for invalid data results, isolated Vehicle Noise Testing facilities would need to be established. These facilities could allow vehicle owners to take their vehicle for annual Drive-by Monitoring. Only one vehicle would enter the specialized testing area at a time, to allow for isolated and accurate testing.

Options to Address Vehicle Noise that Does Not Involve Testing

Parsons researched methods to address vehicle noise that would not requiring testing during the annual vehicle inspection.

Visual Only Inspection

One option to address vehicle noise without physical testing is to add visual examination requirements to the AVIP application. The inspection application could be modified to require an Inspection Mechanic to look for non-OEM modifications of the tailpipe. The application would leave a non-compliance determination up to the Inspection Mechanic or Law Enforcement in the field. Additionally, the Inspection Mechanic would be required to check on the exhaust and tailpipe emission components and fail vehicles for damaged, weakened, or rusted components.

Public Education Campaign

Another option to address vehicle noise without requiring testing would be to educate the public about vehicle noise. Conducting a public education campaign about the impacts of vehicle noise on the health of both individuals and the community in general would not involve vehicle testing. The campaign would include helpful tips and guidance regarding vehicle noise. The information would discuss the purpose of aftermarket tailpipes, and how they may impact the vehicle noise pollution.

The campaign may be targeted as well, targeting those utilizing aftermarket tailpipes and encourage the installation of fiberglass matting, ceramic wool, or other Sound Deadening Materials. By adding enough "mass" to the muffler, it will change the frequency of the vibration inside the muffler, lessening the vehicle noise. “Helpful tips” could include information around affixing tailpipe silencers to the end of the muffler.

Legislation

The Vermont Legislative Assembly could pass legislation addressing vehicle noise. Options could include:

- requiring that every motor vehicle be equipped with a muffler in good working condition,
- banning the application of aftermarket tailpipes
- prohibiting the use of a muffler that emits “excessive or unusual” noise
- prohibiting modification that would cause the muffler to emit more noise than the original, factory installed muffler.

It is worth noting that similar legislation has passed in nearly 20 states and the District of Columbia. Enforcement techniques would need to be explored.

Vehicle Noise Reduction Study

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